PETROLEUM DEVELOPMENT AND TECHNOLOGY

1938

PETROLEUM DIVISION

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Volume 127

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PETROLEUM DIVISION

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FOREWORD

It is a pleasure to write this foreword to the Petroleum Division's volume of TRANSACTIONS. The three meetings of the year—at Los Angeles, Oklahoma City and New York—resulted in a larger number of papers of acceptable quality than usual. All the meetings were of vigorous character, particularly in respect to discussion of papers presented. The subject matter covered the origin of oil, notable recent discoveries in California, technique of various phases of exploitation, reservoir behavior, and a particularly notable session on economics.

The guest speaker at the Annual Dinner, Mr. Whiting Williams, gave a highly interesting and entertaining word picture of experiences with labor and labor relationships.

The effort to improve the usefulness of the Petroleum Division has resulted in two steps, as follows: (1) approval by the Board of Directors of the engagement of a man intimately acquainted with the petroleum industry as an Assistant Secretary of the Institute, to be attached to the New York office, and (2) the establishment of PETROLEUM TECHNOLOGY, a quarterly publication to be devoted to the more prompt publication of technical and economic papers of interest to engineers engaged in petroleum work. Publication was initiated with the issue of February 1938. A major duty of the new Assistant Secretary will be to serve the Petroleum Division, and much of his time is to be spent in maintaining effective contact with men in the industry by personal visits.

In contrast with recent preceding years, there was no program session on stabilization at the Annual Meeting. It should not be assumed that the chairman of this committee was inactive, or that important progress was not made in this committee's work during the year. With a background such as developed by this committee's work over this and preceding years, the preparation of papers like that delivered by Dr. Alexander Sachs* at the session on economics is stimulated, and they have a favorable reception. Space in this foreword does not permit mention of other significant papers and efforts relative to stabilization during the year.

Under the chairmanship of John Suman, the Lucas Medal Award Committee awarded the medal to Henry L. Doherty, for his great service in bringing about general recognition of the proper function of gas in the production of oil.

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* As yet unpublished.

The preparation and publication of statistics on petroleum production continues as an important service by the Institute.

To the great regret of members in the Petroleum Division, came the retirement of Dr. Eugene A. Stephenson, University of Kansas, as the elective Secretary-Treasurer. Fortunately, Dr. Stephenson will continue active in Division affairs. B. C. Craft, Louisiana State University, the newly elected Division Secretary-Treasurer, is well and favorably known to most of us through his activity in Institute affairs.

Such success as the Division has had during the year has been due to cooperation of many individuals, both those in official positions and others. Particular recognition is due those who have contributed papers. It is of interest to observe that many of the foremost contributions come from those attached to universities and colleges.

M. Albertson, *Chairman*,
Petroleum Division, 1937.

PLANS OF THE PETROLEUM DIVISION FOR 1938

By G. B. Corless, Chairman of Division

With the inauguration of Petroleum Technology this year, and approval by the Board to add an Assistant Secretary to the New York staff to serve the Petroleum and Coal Divisions, the Petroleum Division looks forward to greater opportunities and responsibilities. An improved medium of publication offers further incentive to engineers and investigators in the oil industry to make contributions.

The authorization by the Board of Directors of a new Assistant Secretary is an appreciation of the splendid contributions made to the industry by the open forum of the Petroleum Division. It is also a recognition of the possibilities of greater service to the membership along the lines established ten to fifteen years ago by DeGolyer, Fohs, Ambrose and Lovejoy, to mention a few leaders. It is expected that the new officer will spend a substantial part of his time in the field, visiting the student sections, the respective Divisions, helping in the arrangement of papers and Section meetings and intensifying interest in the Institute.

The Petroleum Division will hold three meetings this year. The Fall Meetings will be held on Oct. 6 and 7 in San Antonio and on Oct. 20 and 21 in Los Angeles. The programs for these meetings will deal chiefly with engineering research and production engineering problems. Papers on production statistics and general economics of the industry are reserved for the Annual Meeting in New York. The annual production symposium and statistics are accepted as standard for the industry.

With continuously deeper penetration into the earth in search for and exploitation of petroleum, it is necessary to have a better understanding of reservoir conditions and to place more phases of the operation under engineering control. Among the subjects relating to reservoir conditions tha thave been proposed for the fall meeting programs are phase equilibria at high pressures, interfacial tension between oil and water, the flow of oil and water through sands, the chemistry of films and underground temperatures. Investigations relating to control of operations include methods of continuously logging while drilling both visually and electrically, methods of studying drilling samples, properties of drilling fluids, improved cementing practices for isolating thin sands under high-temperature conditions and gas conservation, particularly production from high-pressure reservoirs.

Additional suggestions of general themes or individual subjects will be welcomed, since it is desirable to build a backlog of material for Petroleum Technology.

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THE ANTHONY F. LUCAS GOLD MEDAL

In 1936 the Institute established the Anthony F. Lucas Gold Medal, which will be awarded from time to time "for distinguished achievement in improving the technique and practice of finding and producing petroleum." These awards will be sponsored by the Petroleum Division.

Captain Lucas was a pioneer in the oil industry, one of the early wildcatters and a leading mining and petroleum engineer. He was famous as the discoverer of Spindletop. He became a member of the Institute in 1895 and in 1913 was the first Chairman of the Petroleum and Gas Committee of the Institute, the forerunner of the present Petroleum Division. He also headed the Committee in 1914, 1917 and 1918.

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Chapter I. Production Engineering

Spacing of Oil Wells

By Lyndon L. Foley,* Member A.I.M.E.

(Oklahoma City Meeting, October, 1937)

The proper spacing of oil wells is a problem of vital importance to the oil industry. Conservation demands a maximum recovery, while economic considerations attach primary importance to profitable extraction of oil. Formulas have been evolved,[1–4] which attempt to solve the spacing problem mathematically, using reservoir characteristics as factors. Comparisons have been made of fields producing from supposedly similar sands, which have been drilled to varying densities,[5,6] and also of different leases in the same field.[5–8] Intermediate wells have been drilled in old, depleted fields to test the efficiency of drainage by the original operation.[9–11] Intermediate wells have been drilled also to obtain cores of the depleted sand for analysis, from which to learn the degree of efficiency of extraction. The problem is being attacked by many students, and along several different lines.

Unfortunately, the fields now depleted were produced generally without restriction, and conclusions drawn from them may not apply to fields operated under restricted production. Reservoir conditions in a restricted field, especially reservoir pressures and pressure gradients within the reservoir, are quite different from those in a field produced to capacity.

Many people have held the idea that the closer the spacing, the greater the recovery. This general statement is not always true, as other factors than well spacing enter into the recovery problem. Cutler,[5] who has been quoted frequently by advocates of close spacing, limited his conclusions to gas-drive fields, and to the particular fields and spacings that he investigated. Hill and Sutton[7] analyzed four tracts in the Powell field; the tract most closely drilled had the third largest recovery per acre-foot, and the tract with the widest spacing had the second largest recovery per acre-foot. A search of the references to well spacing in the publications of the U. S. Bureau of Mines[5,13–19] discloses repeated condemnations of the wastefulness of the practice of town-lot drilling.

Manuscript received at the office of the Institute Sept. 15, 1937; revised March 19, 1938.

* Consulting Petroleum Engineer, Tulsa, Oklahoma.

[1] References are at the end of the paper.

This same general statement is certainly not true of all fields under proration, as was shown by Suman[12] and by Cattell and Fowler.[13] It may be especially untrue in prorated fields in which minimum allowances are applied. The total of the minimum allowances of the wells may exceed the most efficient rate of production for the field.

RESERVOIR ENERGY IN RELATION TO RECOVERY OF OIL

Recovery of oil is dependent upon energy in the underground reservoir, either natural or induced.

The oil in a natural reservoir may be classified as follows:

A. Oil that adheres to the reservoir rock
B. Oil capable of moving, or *recoverable* oil
  1. Recoverable oil left in reservoir
  2. Oil that is recovered
    a. By natural drive
    b. By artificial drive

It is known that 100 per cent recovery is never achieved. A certain amount of oil remains in the reservoir rock and is not recovered even by the most efficient water drives. All oil that is capable of moving out of a given unit of reservoir rock is recoverable oil. The oil that is moved into the well bore is the oil that is actually recovered, and may be only a fractional part of the recoverable oil. Our experience with secondary recovery methods has shown that much recoverable oil was left in the reservoirs by early production methods. Oil is moved into the well bore by reservoir energy; when the reservoir energy is exhausted, oil ceases to move. The addition of artificial reservoir energy by means of gas or water drives has increased recoveries greatly in many fields. The general success of secondary recovery methods shows that the apparent depletion of oil pools has been caused more commonly by exhaustion of the reservoir energy than by removal of all of the recoverable oil. It appears that the problem of maximum natural recovery of oil is largely a problem of maximum efficiency in the utilization of reservoir energy. This consideration suggests that the well-spacing problem and the problem of reservoir energy are closely related Knowlton[20] said: "The use of reservoir energy is in effect a substitute for the drilling of wells and the more it is conserved the fewer wells are necessary."

SOURCES OF RESERVOIR ENERGY

There are three sources of reservoir energy: (1) water, (2) gas, (3) gravitation.

1. The most important source of energy is the pressure of water adjacent to the oil in the porous rocks.

2. Gas under pressure is a very important source of energy in many fields. It may exist as free gas in a gas cap or as gas dissolved in the oil.

The free gas supplies energy proportional to its amount and to its pressure, the latter usually determined by the pressure of adjacent water. Dissolved gas may come out of solution on reduction of reservoir pressure, forming gas bubbles throughout the porous reservoir and furnishing a source of energy for moving recoverable oil. Some of the gas released from solution may go into the gas cap.

3. In reservoirs lacking pressure from water or gas, gravitation may cause pressure gradients in the oil itself and may cause a slow seepage of oil into wells or mine workings. Gravitation might be considered the primary source of reservoir energy, since it causes the pressure in fluids in artesian basins.

The pressure found in oil reservoirs usually approximates the normal pressure of an artesian basin of the same depth. Lenticular or shoestring sands and other isolated porous zones may contain fluids under abnormally low pressures, which are common. Pressures conspicuously higher than the normal artesian pressure for the given depth appear to be rare except on the Gulf Coast. Weaver has suggested[21] that such condition may be caused by seepage of high-pressure gas from deeper horizons.

The first two sources of energy mentioned are of greatest importance in oil production. They may be recognized and their relative effects may be evaluated rather accurately by the use of reservoir-pressure data, particularly the rate of pressure decline per unit of oil produced at different rates of flow, and the behavior of the reservoir pressure when the field is shut in or severely restricted.

A field under water drive will have normal reservoir pressure when it is first tapped, but the pressure tends to decline when the fluids are set in motion. The depleted pressure of a reservoir under water drive may be built up if the field is shut in or severely restricted, and it is by this characteristic that the activity of water drive may be indicated. This is illustrated in Fig. 1, which shows the reservoir-pressure history of the East Texas field. The increases in pressure at *A*, *B* and *C* were caused when the field was shut in by Government orders. The increases at *D* and *E* were caused when the field outlet was restricted. By producing any water-drive field at different rates of flow, a rate of volumetric withdrawal may be established at which the reservoir pressure remains approximately static, and so the effectiveness of the water drive may be evaluated in terms of units of water encroachment per day. Water drive balances production in the following fields at the approximate rates given: Yates field, Texas, 45,000 bbl. per day;[22] Hobbs field, New Mexico, 33,000 bbl. per day;[23] East Texas field, Texas, 400,000 bbl. per day.[24]

Fields under gas drive tend to have the same rate of pressure decline per unit of oil produced for all rates of flow if the gas-oil ratio remains constant. The rate of pressure decline per unit of oil produced will respond quickly to variations in the gas-oil ratio. In a field under gas drive only, the depleted pressure will remain static when the field is shut in. Discussions of the mechanics of pure gas drive have been given by Herold[26] and by Coleman, Wilde and Moore.[27]

A great many fields are subject to water drive and at the same time have a free gas cap. Such fields may show characteristics of both drives. At rates of withdrawal lower than the rate of water drive, the field will show the characteristics of a water-drive field. The characteristics of gas drive will predominate at higher rates of withdrawal, and may mask the effect of water drive. This is illustrated by the Yates field, which shows the characteristics of a gas-drive field at rates of production more than 45,000 bbl. per day, and water-drive characteristics when producing less than 45,000 bbl. per day. It must be remembered that the volumetric withdrawal is the critical figure, and that any material change in gas-oil ratios or in water production will affect the critical rate of *oil* production for a given water drive.

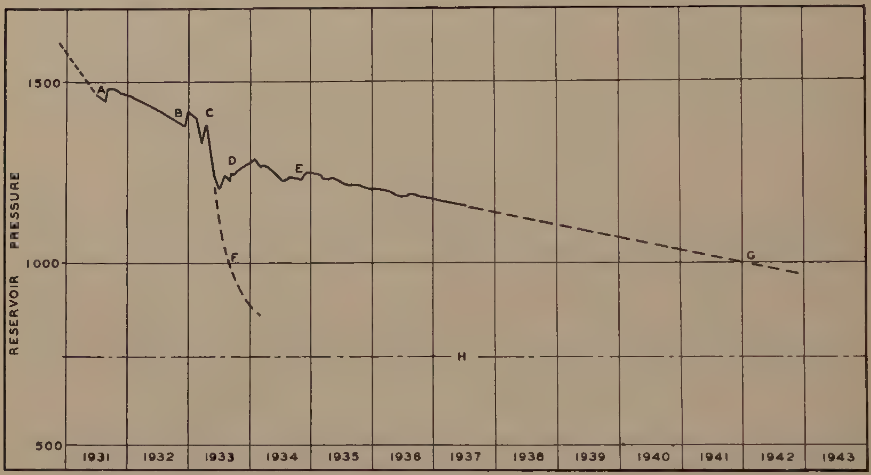

FIG. 1.—RESERVOIR-PRESSURE HISTORY OF THE EAST TEXAS FIELD.
A, B, C, pressure increases caused by shutting in field.
D, E, pressure increases caused by restriction of field outlet.
F, G, pressure at which artificial lift is usually necessary.
H, pressure at which gas begins to come out of solution.
Data after W. S. Morris: General Conditions in the East Texas Field. *Oil Weekly* (1937) **85**, No. 12, 38.

It is often stated that certain fields have no water drive. Attention is called to the critical production rates of the previously mentioned fields as expressed in terms of barrels per acre per day. These critical rates at which water drive balances production are, approximately: Yates field, Texas, 2.25 bbl. per acre per day; East Texas field, Texas, 3 bbl. per acre per day; Hobbs field, New Mexico, 5 bbl. per acre per day. Water drive should not be considered lacking until the reservoir-pressure performance has been studied with the field shut in, or restricted to rates of production as low as 1 or 2 bbl. per acre per day.

UTILIZATION OF RESERVOIR ENERGY

Energy of water drive may be utilized efficiently by producing the oil at rates not exceeding, or exceeding only slightly, the rate of effective water drive. Enough wells should be drilled to permit this withdrawal without creation of local low-pressure areas. The volume of water produced with the oil should be restricted as much as possible, as the water produced contributes to the pressure decline. Water produced with the oil may be returned to the producing sand in edge wells or in dry holes. This is a conservation measure, as it helps to maintain the reservoir energy that moves the oil.

The efficient utilization of water-drive energy, and the advantages thereof, are well illustrated in the East Texas field. During May and June 1933, the field was produced at rates as high as 1,000,000 bbl. per day and the reservoir-pressure decline was about 5 lb. per sq. in. per day. The production of the field was then reduced gradually to about 450,000 bbl. per day and the reservoir pressure increased for several months as shown at *D* in Fig. 1. Had the high rate of pressure decline continued until August 1933, the average pressure of the field would have been down to 1000 lb. per sq. in., the pressure at which artificial lift usually becomes necessary, and the total production to that time would have been about 460,000,000 bbl. The average pressure of the field, if present operating conditions continue, will decline to 1000 lb. per sq. in. about the end of the year 1941, by which time the field will have produced approximately 1,800,000,000 bbl. of oil. The high rate of production prevailing in May and June 1933 would, in a few months, have reduced the average reservoir pressure to 740 lb. gauge, the pressure at which gas begins to come out of solution and leave dead oil in the sand.

The energy of reservoirs under gas drive may be conserved by maintaining the lowest possible gas-oil ratios. The most efficient rate of production for such fields is the rate at which the lowest gas-oil ratio may be maintained, and which in turn depends on the gas-oil ratios of individual wells and on the number of wells in the field.

In fields in which both water drive and gas drive are present, both forms of energy should be conserved. The field outlet should be kept near the effective rate of the water drive. Water production should be restricted, since it increases the volumetric withdrawal per unit of oil. Low gas-oil ratios should be maintained in order to conserve the gas pressure and to minimize the volumetric withdrawal per unit of oil.

Water Drive versus Gas Drive

Theoretically, one well properly placed in a reservoir under water drive should recover all of the recoverable oil if given enough time.

The time required for one well to drain the reservoir might be impractically long and, as in the East Texas field, for example, it might be impossible to produce daily from one well the amount of oil the reservoir is capable of producing. It may be necessary to drill a number of wells to utilize the water drive fully each day. By producing the field at a rate equal to the effective water drive, the initial reservoir efficiency may be maintained throughout the life of the field. Recoveries of oil in water-drive fields may be as high as 50 per cent or more.

The mathematical theory of gas drive indicates that an infinite number of wells, all starting to produce simultaneously, would be needed to recover all of the recoverable oil.[26–28] It is impossible to drill an infinite number of wells, and spacing in a gas-drive field must be wide enough to allow each well to yield sufficient oil to return a profit to the operator. This theory is based on unrestricted production. Many engineers believe that modern gas-conservation methods, applied to restricted fields, will permit the recovery of the recoverable oil with fewer wells. It must be remembered that, as the pressure in a gas-drive reservoir declines, gas comes out of solution from the oil remaining in the reservoir, gas-oil ratios increase, and the efficiency of the reservoir performance decreases through the life of the field. It has not yet been shown that gas drive with wider spacing and gas-oil ratio control will give as complete recovery as water drive with the same spacing. Recoveries actually attained in fields operated under gas drive appear to have been of the order of 20 to 25 per cent, although many engineers believe that these recoveries will be increased by modern production methods.

Water drive requires fewer wells than gas drive to attain a given recovery. Water drive probably will give a greater ultimate recovery than gas drive for any well spacing that is economically practicable.

Many fields are subject to combination drives, and a pure water drive may be changed to combination drive by excessive rates of withdrawal, which would reduce the reservoir pressure and bring gas out of solution. It is optional with the operators of such fields to produce them by gas drive or by water drive. The oil may be produced at a rate considerably in excess of the effective water drive. This results in rapid pressure decline, short flowing life, gas being released from solution and dead oil left in the sand. On the other hand, the field may be produced at a rate equal to the effective water drive with little or no reservoir-pressure decline and have a long flowing life, the gas being retained in solution so that the water drive will be working against live oil, with a greater ultimate recovery. Operating combination fields under water drive will give a more stable current supply of oil.

It must be emphasized again that water drive should not be considered lacking until the field has been tested at rates of flow as low as 1 or 2 bbl. per acre per day. It must be admitted that wells 6000 ft. deep, on

10-acre spacing, cannot be operated profitably at 2 or 3 bbl. per acre per day. Wells on 40-acre spacing or wider could be operated on such daily per acre allowances, ultimate recoveries would be higher than with closer spacings under gas drive, and a large part of the oil would be produced by natural flow. If water drive is absent, or effective only at impractically low rates, the field can be drilled to a greater density for gas drive.

To summarize: Reservoir energy may be utilized efficiently by operating oil fields in such a way as to maintain minimum gas-oil ratios, to produce a minimum amount of water, to maintain a slow pressure decline and to avoid the formation of low-pressure areas. The field should be operated as a water-drive field if water drive is present.

Suggested Solution of the Spacing Problem

The following procedure is suggested to solve the spacing problem in a new field. After discovery, the field might be outlined by exploratory wells on a rather wide spacing pattern. The field could then be studied at varying rates of production to determine the nature of the reservoir energy and the effectiveness of the water drive. The rate of production that utilizes reservoir energy most efficiently could be determined. During this time, considerable data on the performance of individual wells would accumulate. Development could then be planned to drill such a number of wells that each well might operate at its own most efficient rate, and the total of the production of all of the wells in the field equal the rate at which the field itself would utilize its reservoir energy most efficiently. This procedure would yield the maximum natural recovery with the minimum development cost consistent with efficiency.

The spacing problem may be solved for a water-drive field by dividing the rate of effective water drive by the efficient production rate of the average well. The quotient is the number of wells that should be drilled. This solution may be applied to the East Texas field, as an example. Suppose that the average well in this field can produce 100 bbl. per day without local physical waste. The field is now producing about 450,000 bbl. per day with a reasonably low rate of pressure decline. Then 4500 wells, each producing 100 bbl. per day, could produce the field's allowable production. This would correspond to a spacing of about one well to 30 acres.

The problem may be solved for gas-drive fields by dividing the current market demand for oil from that field by the rate at which the average well has the lowest gas-oil ratio. This gives the number of wells required to produce the market demand efficiently. The probable reserves of the field should be divided by the ultimate recovery per well necessary for profitable operation. This gives the maximum number of wells that may be operated profitably. The *smaller* of the two quotients is the number of wells that should be drilled. If the first quotient is larger, part of the market demand should be surrendered to other fields, as supplying that demand would call for excessive drilling, or excessive production from a smaller number of wells.

If a field is found to have both water drive and gas drive it should be developed and produced as a water-drive field, in order to achieve the greatest natural recovery of oil.

The procedure suggested above could be applied easily in fields under one ownership, or in fields that can be unitized. In many fields, there are tracts that are smaller than a normal drilling location. It might be possible to unitize small tracts into drilling sites without necessarily unitizing the field. If efforts to unitize fail, and if small tracts are drilled with close spacing, a proper acreage factor in proration will prevent unequal drainage and will relieve surrounding operators of the necessity of close drilling to protect their royalty owners. It then becomes optional with the operators to choose close spacing with small per well allowable production, or wider spacing with larger per well allowable production.

Lewis[29] has shown that safety is in the direction of wider spacing. Too wide spacing can be cured by additional drilling or by repressuring. The money lost through unnecessary drilling cannot be recovered.

There are reservoirs containing small, disconnected zones with relatively large accumulations of petroleum. There are fields in which the production comes from fractures; fields of very erratic porosity and fields badly faulted are examples of this class. The principles applied to more uniform pools may not apply to fields of this kind, and it may be necessary to drill more closely as a sporting proposition in order to be sure that all of the rich zones are tapped. The answer to this problem is to learn to drill more cheaply.

CONCLUSION

It appears that the ultimate recovery of many fields has been determined by the degree of efficiency of utilization of reservoir energy, therefore such utilization should be considered of primary importance, and the well-spacing pattern should be designed to give the most efficient use of the energy in the reservoir.

Each field should be tested carefully for water drive, and it should be utilized if present. Water drive permits wide spacing with low development costs, long flowing life, low lifting costs, and the maximum natural ultimate recovery.

The proper solution of the well-spacing problem for water-drive fields is to divide the efficient rate of production for the field by the efficient rate of the average individual well. The quotient is the number of wells that should be drilled.

The solution for a gas-drive field is found by (1) dividing the current market demand for oil from the field by the efficient production rate of the average well and (2) dividing the estimated reserves of the field by the ultimate per well recovery necessary for profit. The *smaller* quotient of the two procedures is the number of wells to be drilled.

A field under combination drive will probably give the greatest natural recovery if it is operated as a water-drive field.

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The writer has discussed the problems involved in this paper with a number of engineers and geologists and is greatly indebted to all of them. Especial acknowledgments are due to the Messrs. M. Albertson, F. A. Bush, K. A. Covell, J. T. Hayward, T. V. Moore and H. H. Power.

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Gas Caps, Their Determination and Significance

By P. P. Gregory,* Member A.I.M.E.

(Oklahoma City Meeting, October, 1937)

Natural petroleum gas occurring in the oil-bearing reservoirs is found to exist either as free gas associated with the oil and/or in solution in the oil. In some virgin fields practically no free gas is encountered under the reservoir conditions of pressure and temperature, although in other fields a considerable section of the "pay" horizon is occupied by free gas. In other words, a given oil field may or may not have a gas cap before the exploitation takes place. However, when the reservoir pressure is reduced to a point below the critical saturation pressure by withdrawals of fluids from the producing formation, the gas dissolved in the oil inevitably begins to come out of solution and becomes free gas. Under the controlled methods of production and drilling, a portion of this gas is produced with the oil to the surface and a portion of it remains within the reservoir to accumulate at higher structural levels toward which it migrates by virtue of its low specific gravity. The rate of growth of a gas cap in a given structure depends primarily upon the rate of decline in the reservoir pressure. If the rate of pressure decline is rapid, the gas cap likewise will grow rapidly. On the other hand, shrinkage in the gas-cap area was noted in some fields in which reservoir pressures were increasing.

Determination of Gas-oil Contact and Thickness of Gas Cap

The gas-oil contact can be conveniently located in the process of drilling a well and by electrical logging. However, very little can be found in the petroleum literature concerning methods of predetermining gas-oil contacts in producing reservoirs. Therefore, the writer feels justified in describing briefly a simple, workable, and inexpensive method of determining gas-oil contacts and outlining the limits of gas-cap areas in a field where such knowledge may be essential for efficient production and development operations.

The method involves the determination of the following data: (1) Structural data, such as the depth or elevation of the top of "pay" horizon; (2) reservoir pressures; (3) tubing and casing pressures at the well head; (4) static oil-pressure gradient; (5) static gas-pressure gradient. These data can be secured with a minimum of expense, inasmuch as the

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structural data are obtained at the time of the drilling of the well, and the determination of reservoir pressures has become one of the routine duties of a petroleum engineer in most of the major fields. The static oil-pressure gradient may be determined with a recording subsurface-pressure gauge at two or more depths in the well *in oil*, by dividing the observed pressure differential by the difference in depth. The static gas-pressure gradient can be determined from the pressure-volume relations of a representative sample of the casinghead gas by observing the specific volume of the gas, in cubic feet per pound, at different well-head pressures.

To illustrate the method, three sample calculations were prepared on wells in an oil field having a mid-point of the pay section at an elevation of 1300 ft. below sea level—the elevation that will be used here as a reference datum. The producing reservoir has a structural closure of some 300 ft. and has large accumulations of free gas in structural highs. The average static oil-pressure gradient is 0.3625 lb. per sq. in. per foot of depth, and a typical sample of the casinghead gas has the following pressure-volume relations:

Well-head Pressure, Lb. per Sq. In. Gauge	Specific Volume (at Reservoir Temperature), Cu. Ft. per Lb.
1,000	0.2695
1,100	0.2424
1,200	0.2199
1,300	0.2009
1,400	0.1849
1,500	0.1709

A graph showing the pressure exerted by a static column of gas, pounds per square inch per foot of depth, can be constructed by using reciprocals of the specific volume divided by 144 at corresponding well-head pressures.

Example 1.—Well A has the following data:

Tubing pressure, lb. per sq. in.	500
Casing pressure, lb. per sq. in.	1300
Pressure at −1300-ft. datum, lb. per sq. in.	1492
Depth to −1300-ft. datum, ft.	3642
Elevation of top of pay, ft.	−1150

Elevation of the gas-oil contact then can be determined from the following formula:

$$P_D = P_c + G(D - x) + G_1x$$

where P_D is the datum pressure,
P_c, casing pressure,
G_1, static oil-pressure gradient,
G, static gas-pressure gradient,
D, depth to datum,
x, distance between datum and contact.

Substituting known values in this equation:

$$1492 = 1300 + 0.0346(3642 - x) + 0.3625x$$
$$x = 201 \text{ ft. above the datum, or,}$$

Elevation of gas-oil contact is minus 1099 ft.
Elevation of top of pay is minus 1150 ft.
Therefore there is no free gas in the pay zone.

Example 2.—Well B has the following data:

Tubing pressure, lb. per sq. in.	620
Casing pressure, lb. per sq. in.	1350
Pressure at −1300-ft. datum, lb. per sq. in.	1492
Depth to −1300-ft. datum, ft.	3630
Elevation of top of pay, ft.	−1140

$$P_D = P_c + G(D - x) + G_1x$$

Substituting known values in the equation and solving for x,

$$1492 = 1350 + 0.036(3630 - x) + 0.3625x$$
$$x = 35 \text{ ft. above the datum, or,}$$

Elevation of gas-oil contact is minus 1265 ft.
Elevation of top of pay is minus 1140 ft.
Thickness of gas cap is 125 ft.

Example 3.—Well C has the following data:

Tubing pressure, lb. per sq. in.	575
Casing pressure, lb. per sq. in.	1365
Pressure at −1300-ft. datum, lb. per sq. in.	1492
Depth to −1300-ft. datum, ft.	3680
Elevation of top of pay, ft.	−1180

$$P_D = P_c + G(D + x) - G_1x$$
$$1492 = 1365 + 0.0365(3680 + x) - 0.3625x$$
$$x = 22 \text{ ft. below the datum, or,}$$

Elevation of gas-oil contact is minus 1322 ft.
Elevation of top of pay is minus 1180 ft.
Thickness of gas cap is 142 ft.

The accuracy of this method depends primarily upon the precision of reservoir-pressure measurements. Pressure determinations made with a good subsurface-pressure gauge should give reliable results. It is important that pressure measurements shall be made on the wells after the reservoir has attained the condition of static equilibrium. This condition is generally attained after a shut-in period of 24 hr. if the permeability of the producing formation is not too low. Longer shut-in periods may be necessary for areas of low permeability. In numerous instances, gas-oil contact determinations made by this method in one of the fields have actually duplicated the contact data obtained in the drilling of wells.

Determination of Extent of Gas-cap Areas

The gas-oil contact data, when obtained on all of the wells in the field, permit preparation of a map showing the limits of gas-cap areas and the thickness of concentration of free gas within those areas (Fig. 1). In preparing such a map, the data showing the elevation of contact and thickness of the gas cap are plotted opposite the particular wells located on the property map. Contour lines then are drawn through the points of equal gas thickness, using contour intervals of 10 or 25 ft., depending upon the vertical thickness of gas accumulations. The outer contour of the enclosed area on Fig. 1 represents the boundary of free gas accumulation beyond which no free gas was found to occur in the reservoir. Con-

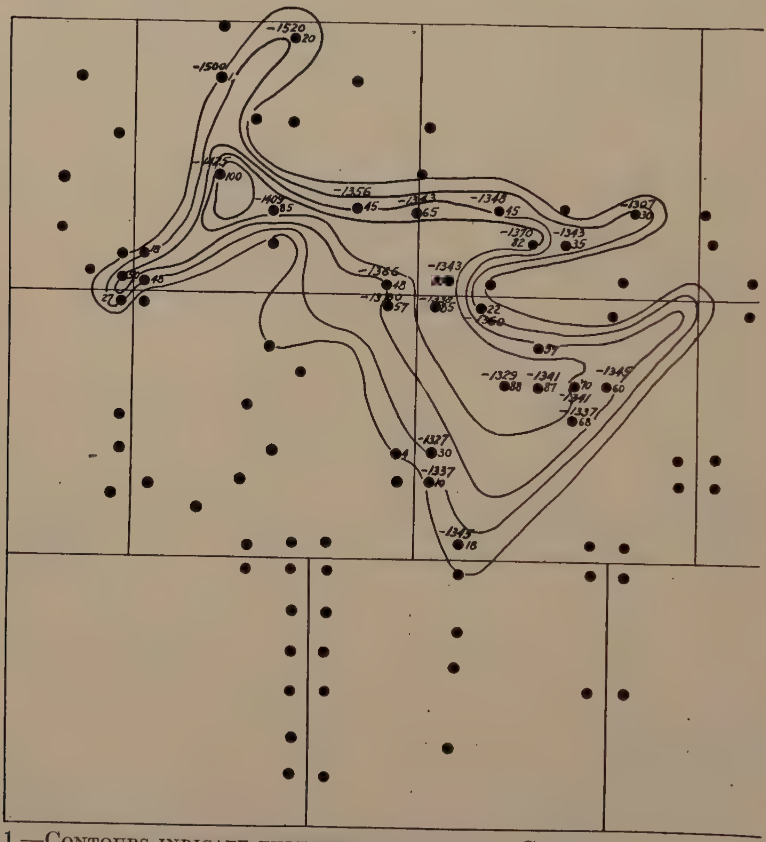

FIG. 1.—CONTOURS INDICATE THICKNESS OF GAS CAP. CONTOUR INTERVAL 25 FEET. SUBSEA ELEVATIONS INDICATE GAS-OIL CONTACT.

tours within the enclosed area represent the thickness of the gas cap, each contour denoting a thickness of 25 ft. Thus, the area enclosed between the outer boundary and the first contour has a thickness of the gas cap varying from zero to 25 ft.; the area enclosed between the first and second contours has a thickness of the gas cap up to 50 ft., etc. A map of this type provides an excellent visual display of the gas-cap situation as of a particular date. Gas-cap maps prepared on a given field at intervals of six months or one year readily disclose the changes that have taken place within the gas cap during that particular time interval.

APPLICATION OF DATA

The knowledge of the position of gas-oil contact and thickness of gas accumulation in the reservoir can be of great help in the solution of various problems encountered in the development and production operations. For example, in the drilling of a well in the gas-cap area, it is always desirable to carry the oil string through the formation occupied by the gas and to exclude the upper free gas. Predetermination of the casing point, therefore, is very important. The downward movement of the gas-oil contact often brings about the condition of insufficient submergence in the well as a result of which the production of oil is obtained with high gas-oil ratios. If the contact data are available, efforts then can be directed intelligently to correct the situation. The gas-cap data are also essential for the work of evaluation of gas and oil reserves in the oil fields.

DISCUSSION

(*M. L. Haider presiding*)

D. L. KATZ,* Ann Arbor, Mich.—Mr. Gregory has given us a method of computing the location of the oil-gas contact in a reservoir. I believe that the major assumption tacitly used by Mr. Gregory in his equation equating gas and oil heads to obtain the gas-oil contact should be scrutinized. The following assumptions were made: (1) the tubing and annular space between the tubing and casing contain uniform liquid; (2) the liquid level between the casing and tubing is at the reservoir gas-liquid contact level.

I will admit that the first assumption is quite possible but I believe that the second assumption will hold only in rare cases. The assumption of a sharp liquid-gas contact in the annular space without foam within 24 hr. after shutting in the well is itself not too probable. Also, there is no reason that the gas-liquid contact in the annulus should be at the reservoir gas-liquid contact, especially in a well that might have a casinghead gas leak. In several pools, I have seen differences of several hundreds of pounds in casinghead pressures among wells of relatively uniform reservoir pressure. As the elevation changes from bottom to top of the pay were less than 200 or 300 ft., all differences over 100 lb. in casinghead pressure when placed in the proposed formula would have indicated that the oil-gas contact varied outside the reservoir itself. Thus it appears to me that it is an exceptional case if the liquid level in the annulus of a well is at the reservoir gas-liquid contact.

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P. P. Gregory.—The assumption that the tubing and annular space contain uniform liquid is quite reasonable. As a rule, the oil string in a well is set at or above the top of pay while the tubing is set in the pay. The maintenance of tubing submergence prevents formation of foam at the gas-oil contact. If permeability of the producing formation is sufficient, the 24-hr. shut-in period is generally ample to permit pressure equalization and separation of oil and gas phases.

Dr. Katz mentioned his experience in observing differences of several hundreds of pounds in casinghead pressures among wells of relatively uniform reservoir pressure. This difference in casinghead pressures may be due to presence of free gas in some wells and absence of free gas in other wells. It may be due in some cases to casinghead gas leaks. Casinghead leaks, of course, should be stopped in order to avoid erroneous interpretation of position of the gas-oil contact in that particular well.

M. L. Haider,* Tulsa, Okla.—How closely will a second or third determination of the gas cap in a particular well check with the first determination if the well is produced between determinations?

P. P. Gregory.—Second or third determinations usually will duplicate or approximate within a very few feet the first determination, under uniform testing conditions. Gas-oil contact determinations made in a certain field at intervals of six months have given remarkably consistent results during the past two years.

H. E. Gross,† Norman, Okla. (written discussion).—In late 1935, during the development of the Stone pool sector of the Burrton-Haven field of Reno County, Kansas, an effort was made to conserve the gas cap by cementing the oil string through it. It was found that the gas-oil contact was not a level plane, but depressed downward toward the heart of the structure. In other words, the gas-oil contact had a lower subsea depth at the center of the gas cap than near the edges. Best conservation practices in this area required cementing the oil string through the gas cap. If there was a question as to the gas-oil contact, it was found by taking drill-stem tests before the casing was run.

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Excessive Pressures and Pressure Variations with Depth of Petroleum Reservoirs in the Gulf Coast Region of Texas and Louisiana

By G. E. Cannon* and R. C. Craze*

(New York Meeting, February, 1938)

This paper discusses the results of a study of reservoir pressures in the Gulf Coast area of Texas and Louisiana, showing the general relation of the reservoir pressure to its subsea depth, as well as excessive reservoir pressures that have been encountered. The latter are particularly important in mud-control work, and the data show why it is necessary to use muds having a relatively high density in many of the deeper wells drilled in this area. Only a comparatively few of the wells drilled in the Gulf Coast that have encountered excessive pressures are discussed, but as far as is known those omitted fall within the range of pressure observed by the writers.

Measurement of Pressures

The following methods were used to determine the values of the original pressures:

1. Estimation of original pressure from subsequent pressure behavior of fields. This method is not precise, and was used only in a few of the older fields in which better methods of obtaining original pressures were not available. Only normal pressures were determined by this method.
2. Measurement of shut-in pressures soon after completion of the first producing well. With one exception, all pressures measured by this method were normal, this well having a pressure slightly higher than normal.
3. Measurements of pressure in connection with drill-stem tests.
4. Estimates from the maximum hydrostatic head of mud that failed to prevent flow from the high-pressure formations into the hole. This method is not exact, tending generally to indicate low pressures.

Normal Pressures

All pressure measurements available are plotted in Fig. 1, with original pressure at the water-oil contact as abscissa and subsea depth as ordinate. All producing fields fall close to the solid line, which passes through the origin and has a slope of 0.465 lb. per sq. in. per ft. By way of compari-

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* Research Engineer, Humble Oil & Refining Co., Houston, Texas.

son, a dashed line is shown, which corresponds to the hydrostatic pressure gradient of salt water containing 8 per cent total solids. (Correction was made for the variation in density of salt water with pressure and temperature.) It was found that this correlation was much better than the

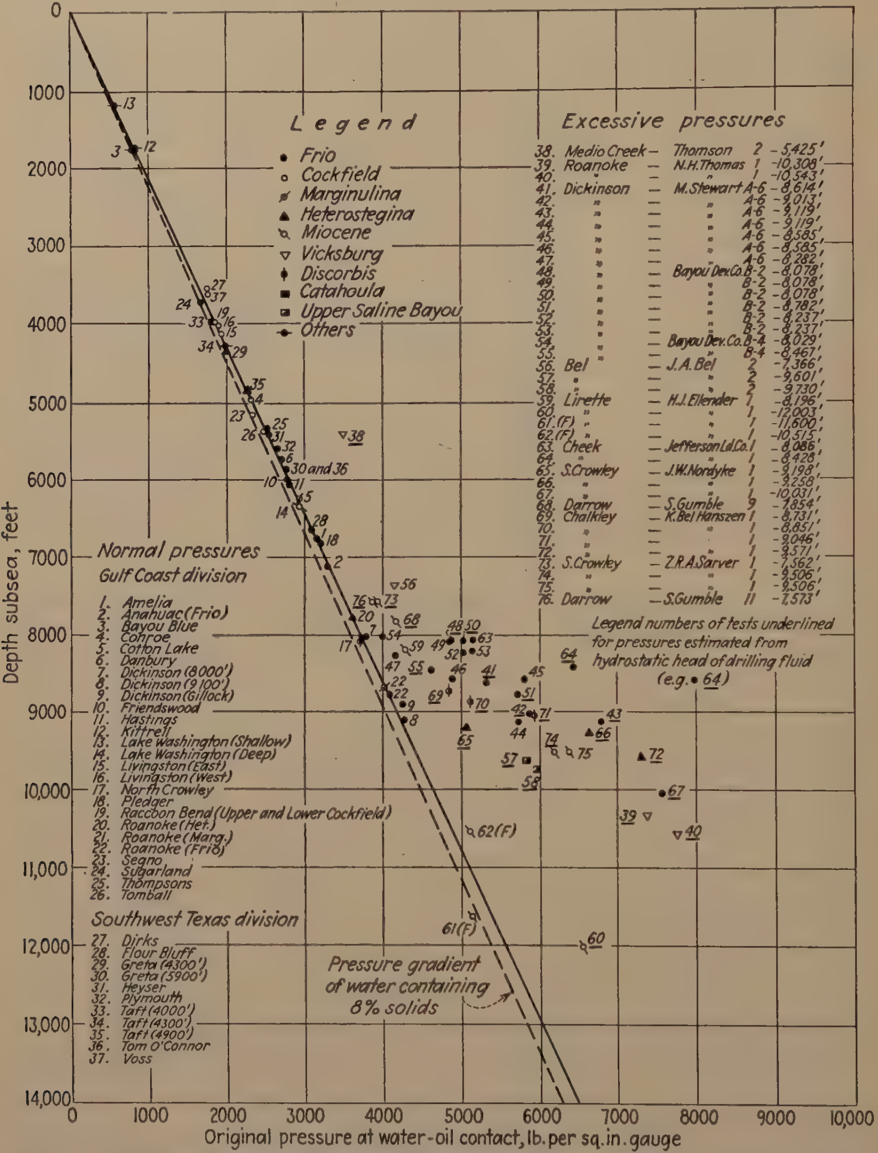


FIG. 1.—RELATION BETWEEN ORIGINAL RESERVOIR PRESSURE AND SUBSEA DEPTH, GULF COAST AND SOUTHWEST TEXAS.

Normal pressures referred to water-oil contact. Excessive pressures referred to depth at which such pressure condition was observed.

made for the variation in density of salt water with pressure and temperature.) It was found that this correlation was much better than the

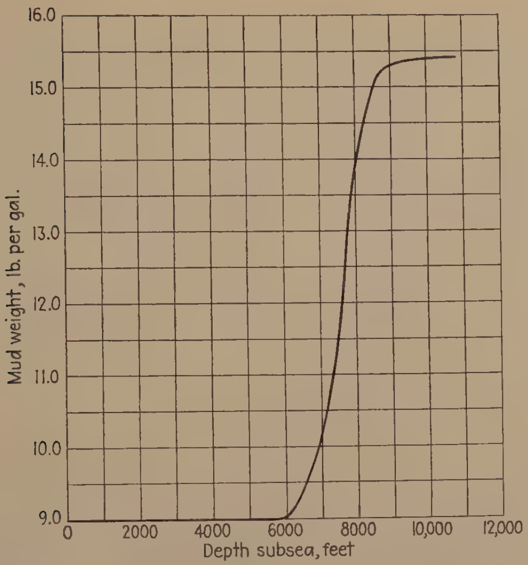


FIG. 2.—MINIMUM MUD WEIGHT NECESSARY TO CONTROL MAXIMUM EXCESSIVE PRESSURES ON THE GULF COAST.

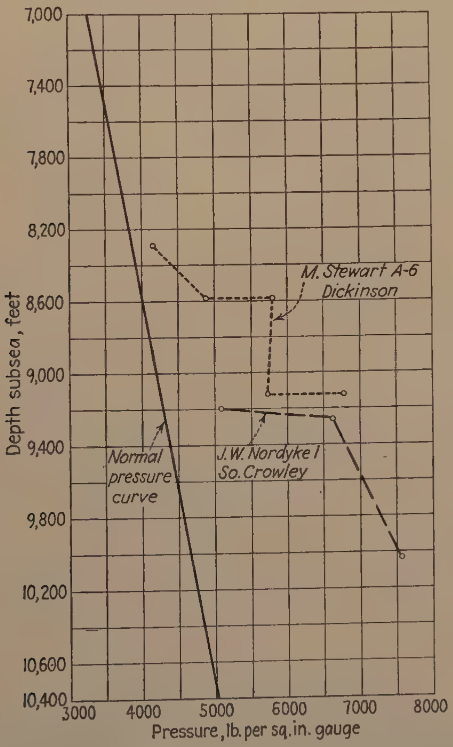


FIG. 3.—EXCESSIVE PRESSURES OBSERVED IN TYPICAL WELLS ON THE GULF COAST.

correlation of pressure with difference in elevation between the water-oil contact and the outcrop of the producing formation. The pressures observed are slightly higher than would be expected from the hydrostatic head of salt water usually occurring in this area. No explanation for this is offered.

It should not be inferred that a mud with sufficient density to control a pressure of 0.465 lb. per sq. in. per foot depth (9 lb. per gal.) can be used safely for drilling in the normal Gulf Coast field. This is the pressure at the water-oil contact, and because of the difference in density between water and oil or gas, substantially high-pressure gradients to the top of the gas or oil sand are encountered. It is believed that this condition, and not excessive pressures, was responsible for the high mud density necessary to drill the early wells in several Gulf Coast fields.

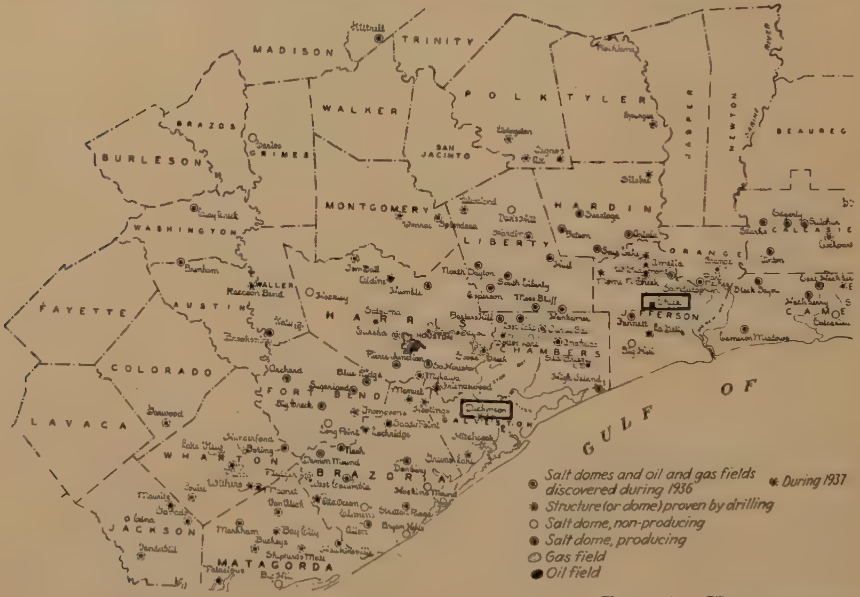


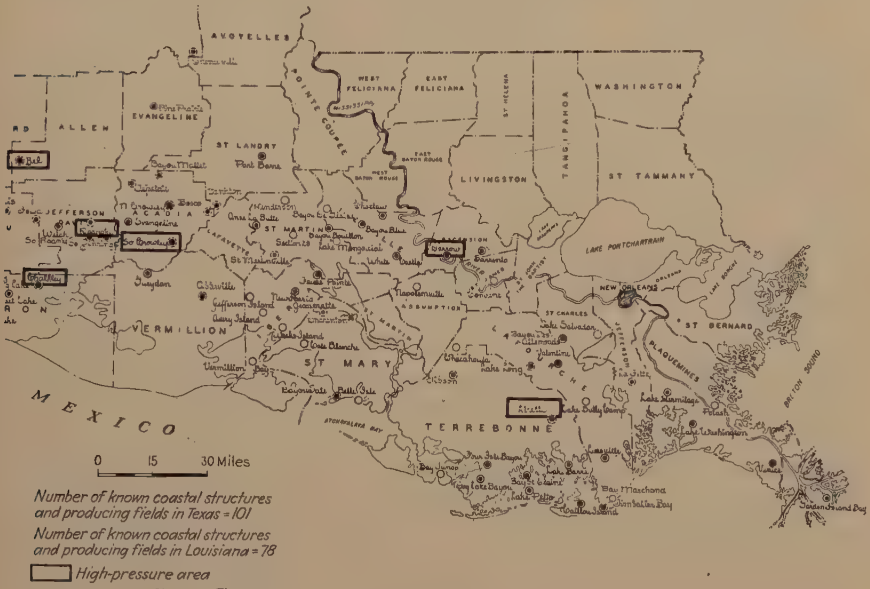
FIG. 4.—HIGH-PRESSURE

Usually, a mud density of at least 9.8 lb. per gal. (51.5 lb. per sq. in. per 100 ft.) is necessary for ordinary drilling in new areas, at depths not greater than minus 7000 ft. This allows a reasonable factor of safety to take care of not only the higher pressures expected in the upper part of gas sands but also of a reasonable reduction in pressure that occurs when the drill pipe is withdrawn.

EXCESSIVE PRESSURES

As indicated on Fig. 1, many wildcat wells encountered pressures substantially higher than normal. The pressures estimated from mud density, which may not be entirely reliable, are indicated. In most cases of excessive pressures, either there was no water-oil contact or it was not known; hence, the depths shown are depths to the sand in which the pressure was observed. With one exception (Thomson 2, Medio Creek district, Bee County), all of these were drilled to depths greater than minus 7000 ft. Pressures as much as 64 per cent higher than the normal value have been observed.

Fig. 2 shows a curve of the mud weight necessary to counterbalance any pressure (except Thomson 2) yet observed. This curve is not to be construed as a recommendation to carry such high mud weight in all wells, but is intended only to serve as a guide to the weight that may be necessary if excessive pressures are encountered. Furthermore, there is no assurance that mud density higher than that called for by the curve may not be required sometimes, although this is not probable.



AREAS ON THE GULF COAST.

In Fig. 3 are plotted the pressures encountered at various depths in several typical wells. The erratic nature of these curves indicates that excessive pressures cannot be predicted from one sand to another, and thus makes it necessary to drill with caution in wells that are likely to penetrate sands of excessive pressure.

The wells encountering excessive pressures as shown by Fig. 1 are widely distributed in the Gulf Coast area, in a strip extending from Bee County, Texas, to Terrebonne Parish, Louisiana, a distance of approximately 500 miles, and from the coast line to as much as 50 miles inland (Fig. 4). Such pressures are not confined to a few horizons, having been observed in the Miocene, Middle Oligocene, Frio, Vicksburg and Upper Saline Bayou.

It appears that there is no geographical or geological correlation of excessive pressures in the Gulf Coast; depth alone seems to govern their occurrence.

THEORIES OF EXCESSIVE PRESSURE

Several theories have been advanced to explain the occurrence of excessive pressure. It appears probable that the sands containing fluid must be of limited extent and in poor communication with sands that are continuous to an outcrop. In some wells—for example, Thomas 1 at Roanoke and the wells in the graben at Dickinson—there is evidence to indicate that the sand lenses are rather small, or that the sand is of very low permeability. In these places, wells blew out but the flow of water or gas quickly subsided. However, at the Bel crater about 7,000,000 bbl. of water has been produced without any appreciable reduction in the rate of flow. This indicates that in this area at least the sand lens containing fluids under excessive pressure has an area of several square miles.

One theory contemplates the isolation of these sand lenses under normal pressure at a depth much greater than that at which they now exist, and that either by earth movement or erosion they have been brought substantially closer to the surface while still retaining the original pressure on the fluids within the sand. This has been suggested by W. E. V. Abraham.[1] The magnitude of the pressures and the history of the Gulf Coast indicate that this is not a probable explanation for excessive pressures in this area, although it may well explain such pressures in other areas.

Another probable explanation is that the sand in these isolated lenses has suffered a decrease in porosity, thus causing an increase in the pressure of the fluids in the pores of the sand. This is plausible but it does not explain satisfactorily the absence of excessive pressures at shallow depths.

The theory that seems to explain the facts most satisfactorily is that at great depths the earth strata are unable to support completely the weight of the overburden, and undergo sufficient compaction, with a corresponding increase in pressure on the fluid in the sands, to permit the fluid pressure and the stress in the earth structure to balance the weight of the overburden. It is interesting to speculate upon the possibility of the upper strata acting as an arch partly supported from beneath almost entirely by fluid pressure, so that any variation in pressure would cause the center of the arch to move up or down. Observations made while pumping mud or dirty water into certain sands indicate the possibility of such an occurrence.

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[1] *Jnl.* Inst. Petr. Tech. (1937) **23**, No. 164, 383.

One other theory has been advanced to explain excessive pressures—that open fissures exist within the earth, filled with gas and connecting with gas reservoirs at great depth, thus permitting the gas under normal pressure at great depth to exert its pressure upon the fluids in sands at shallower depth. In view of the fact that the fissure connecting the upper sands to the lower gas reservoir would probably soon become filled with water, this theory does not seem to be sound.

Conclusions

From the data available, the following conclusions have been drawn:

1. Pressures in most fields of the Gulf Coast are substantially equal to 0.465 lb. per sq. in. per foot depth.
2. Below minus 7000 ft., pressures in excess of this value are frequently encountered.
3. The highest pressure-depth ratio so far encountered was 64 per cent higher than the normal value, and required a mud density of 15 lb. per gal. for its control.
4. The occurrence of excessive pressures cannot be correlated with geographical location or geological formation.
5. The variation in pressure with depth in any well encountering excessive pressures is usually erratic.
6. One explanation for the excessive pressures is that below some depth the earth strata cannot support the weight of the overburden, and are undergoing compaction.

DISCUSSION

(G. B. Corless presiding)

G. B. Corless,* Houston, Texas.—This problem is one we are confronted with on the Gulf Coast with increasing frequency. The cost of weighted drilling fluids and the fact that no important oil accumulations have been found in these abnormal pressure zones makes such drilling very discouraging.

B. B. Cox,† New York, N. Y.—Are there molecular changes that take place in the reservoir that might explain the absence of oil below these zones of abnormal pressures?

L. W. Blau,‡ Houston, Texas.—I do not believe the depths are great enough to cause molecular changes.

M. G. Cheney,§ Coleman, Texas.—Excessive pressures are not restricted to deep reservoirs. A 2200-ft. well in North Texas showed pressures about one-third greater than normal. Presumably this was the effect of actual rock pressure rather than of hydrostatic pressure alone. Extremely low permeability of beds surrounding this sand lens might account for this condition.

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* Superintendent, Gulf Coast Division, Humble Oil and Refining Co.

† Socony-Vacuum Oil Co., Inc.

‡ Director of Geophysical Research, Humble Oil and Refining Co.

§ Petroleum Geologist.

K. A. Covell,* Tulsa, Okla.—Is the temperature gradient parallel with the pressure gradient?

L. W. Blau.—There have not been abnormal temperature gradients. The temperatures measured were below normal because of the conditions of the drilling mud.

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* Assistant Division Manager, Pure Oil Co.

Pressure Drilling Operations at Kettleman Hills, and Effect on Initial Production Rates*

By Read Winterburn†

(Los Angeles Meeting, October, 1937)

This discussion covers only one method of pressure drilling—that developed in the Kettleman Hills field. Thus it is probable that many departures from the procedure herein described would be advisable, and perhaps necessary, in using this method of drilling wells in other localities.

Purpose of Pressure Drilling

By the early part of 1936, formation pressures in the heavily produced north end of the Kettleman North Dome field had declined to range from 1000 to 1500 lb. per sq. in. This low pressure, combined with the depth of the wells (8000 to 9000 ft.) permitted water to be filtered out of the mud into the producing sands during drilling operations. The loss of water was indicated by loss of fluid from the suction tank while drilling, accompanied by an increase in mud weight. It was found that when water was added to the mud stream at such a rate as to keep the fluid level in the suction tank constant, the mud weight would not vary. This indicates that water only was forced into the sands. The rate of this loss at various wells ranged from 2 to 5 bbl. per hour. At some places complete loss of circulation occurred, and drilling mud to the extent of 200 to 1000 bbl. had to be pumped into the sands before returns were regained. It was believed that these conditions had already begun to harmfully affect production, and that such effect would become more pronounced as formation pressures continued to decline. Pressure drilling with oil was introduced because it eliminated the danger of loading the formations with mud and water. The method also afforded a convenient means of testing as drilling progressed, lessening the amount of formation testing, which had become necessary because of encroaching edge water.

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* The writer wishes to acknowledge the cooperation of O. W. Chonette, of the Kettleman North Dome Association, with whom he worked jointly in the original compilation and study of the data relative to pressure drilling. Manuscript received at the office of the Institute Oct. 13, 1937; revised Feb. 21, 1938.

† Petroleum Engineer, Union Pacific Railroad Co., Los Angeles, California.

OPERATION

After the first nine wells had been drilled under pressure, a standard procedure was adopted.

The hole is drilled to the top of the zone to be produced, where 6⅝-in. casing is set. Pressure-drilling equipment is rigged up while the well is standing cemented. After the cement has been drilled out and approval of the water shutoff obtained, the mud is circulated out of the hole with water, which is then replaced by oil of approximately 30° A.P.I., care being taken to eliminate nearly all water from the oil before drilling ahead. The drilling bits are 5⅝-inch.

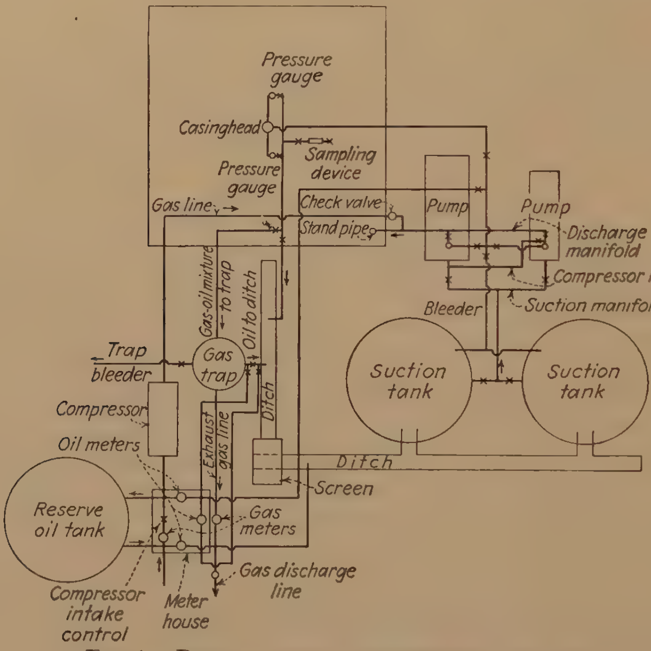

FIG. 1.—PIPING DIAGRAM FOR PRESSURE DRILLING.

Oil is circulated down through the drill pipe, which is packed off above the return flow pipe during drilling, and gas is injected at the desired rate into the standpipe. A portable compressor is used to maintain pressure necessary for injection. Back pressure is maintained by manipulation of a stopcock on the return flow pipe from the casinghead. The gas-injection rate is regulated by means of a valve in the compressor intake line. A check valve prevents oil from being forced into the gas-injection line by a sudden increase in pump pressure.

Returns from the flow pipe are run directly to a gas trap operating under 20 lb. pressure. Gas from the trap is metered, and the oil is returned to the suction tank after passing over a vibrating mud screen. The gas trap is blown down periodically to remove accumulated cuttings.

The following data are kept in hourly record form as drilling progresses: depth, input gas rate, output gas rate, pump pressure, back pressure, gauge on suction tank, pump strokes per minute and length of stroke, compressor suction and discharge pressures, cut and gravity of drilling fluid. All additions to and withdrawals of fluid from the circulating system are recorded.

Before a connection is made, the gas is shut off and the fluid circulated until most of the gas is eliminated, and cold oil is pumped into the drill pipe to prevent back flow. Before a round trip is made, the same procedure is followed, except that sufficient cold oil is pumped into the well to prevent possibility of flow from the casing or from the drill pipe, thus avoiding the possible necessity of pulling drill pipe under pressure.

In the drilling of later wells, standard equipment has been a hydraulic rotary table with packer in conjunction with flush-joint 3-in. drill pipe and a round kelly. Some wells have used a rotating packer with square kelly and conventional rotary table and drill pipe; some, a stationary packer with octagonal kelly and conventional rotary table and drill pipe. A spring-type check valve is placed in the drill pipe at a point just above the casing shoe, to prevent the well from flowing through the drill pipe when the kelly is removed.

It was intended to allow the wells to flow while drilling, but in the first three wells drilled formation pressures were comparatively low, oil used as circulating fluid was rather heavy, and a maximum of 1200 lb. pressure was available for injection, since compressors were not used, therefore it was not possible to induce flow, and the procedure described above was developed.

Testing

When a depth is reached at which it is desired to test, the drill pipe is hung just above the casing shoe or near the bottom of the hole. The gas rate is gradually increased and the pump simultaneously slowed down until completely stopped, and the well thus brought in, flowing through the casing on gas lift. If the well has sufficient pressure, the gas is shut off eventually and the test is completed under conditions of natural flow. After the well has produced long enough to remove all drilling fluid from the hole, rate of flow is determined by meter readings and gauges in the suction tank. Test periods vary from 8 to 24 hr. The amount of water is determined by bleeding the suction tanks each time they are filled. Two suction tanks permit continuous gauging, the oil being pumped to the reserve tank from one suction tank while the other is being filled. All output and input gas is metered. Tests for cut and gravity are run frequently on flow-line and gauge-tank samples. Samples of any water produced are saved for analysis.

Although it is desirable to hang the drill pipe near the bottom of the hole while testing, in order to prevent bridging, the bit is generally hung just above the casing shoe when there is considerable open hole, because of the danger of sticking the drill pipe.

When it is impossible to lighten the fluid column sufficiently to start the well flowing with the bit at the casing shoe, the drill pipe is pulled up to a depth at which the fluid can be gas-lifted from the hole, and is then lowered in stages and the fluid lifted from the hole at each stage until the hydrostatic head has been sufficiently reduced to permit the entrance of fluid from the formation. The test is then conducted as described above.

Factors Affecting Condition of Hole

As might be expected, considerable difficulty has been encountered in keeping the hole open in some of the wells having 300 to 400 ft. of open hole. The factors that probably influence the condition of the hole are: (1) amount of hole drilled; (2) formation of cake on walls of hole by mixture of circulating fluid and cuttings; (3) formation; (4) gas rate; (5) oil rate; (6) cut and gravity of circulating oil.

In wells in which only approximately 100 ft. of hole was drilled, no trouble of any kind was experienced. No difficulties were encountered in any of the wells drilled until more than 100 ft. of hole had been made. This suggests that bridging may have been due, at least in part, to failure to completely remove cuttings from the hole, and that overloading of the fluid with cuttings did not occur until more than 100 ft. of hole had been made. This belief was strengthened when, after pulling a plugged bit in one well, the drill collar was found to be filled with what apparently were very fine cuttings. At another well where several cores were taken, it was found that unless each joint of drill pipe was circulated down in the lower part of the hole, the inner barrel would become plugged with an oily sludge of fine cuttings.

Some cores were coated on their outer surfaces with a material resembling a mud filter cake, which apparently consisted of a mixture of oil and fine silt particles. It is possible that similar material deposited on the walls of the hole may be a factor in the prevention of caving and bridging.

Bridging generally has been found to occur after the making of flow tests. Naturally, the entrance of fluid from the formation would remove any cake that might be present on the face of the sands, and might also be expected to carry some sand into the hole.

It is believed that gas injection aids in carrying cuttings to the surface through increased velocity of flow and possibly also through the buoyant effect of gas bubbles that adhere to the cuttings. However, in the data available there is some evidence that too high a rate of gas injection may have a harmful effect on the condition of the hole, probably because of the surging and heading of the fluid that generally occurs with increased gas rates.

Too low a rate of pumping fluid would naturally result in incomplete removal of cuttings from the hole. Of course the pumping rate and the gas-injection rate are closely related, and it is their combined effect that carries cuttings out of the hole.

The water content of the oil used in drilling has been found to have a direct effect on the condition of the hole. Sump oil was generally used as circulating fluid in most of the first eight wells drilled. At one well having 437 ft. of open hole, trouble was experienced in keeping the hole open. The oil in the hole was found to contain 30 per cent water in emulsified form. Prior to this, checks on the water content had not been made at all wells. It is thus possible that excessive water in the circulating fluid was the cause of trouble at other wells.

Underreaming before running of the liner greatly increased bridging in one well. All later wells were completed without underreaming.

It is significant that only one of the last six wells drilled has had difficulty with the condition of the hole, and in this well the trouble was directly attributed to the contamination of the drilling fluid with water from a leaky connection to the hydraulic packer.

The elimination of hole trouble coincided with the adoption of the standard procedure of using clean oil as circulating fluid, maintaining the rate of pumping oil at from 3 to 4 bbl. per minute, the rate of injecting gas at approximately 200 M cu. ft. per day, and holding 40 to 60 lb. per sq. in. back pressure on the casinghead. It is thought that the most important single factor is the use of clean oil as circulating fluid.

It is probable that many of the wells could have been flowed while drilling. In the producing formations, however, individual oil sands are sometimes separated by 70 or 80 ft. of barren sediments. It was feared that in drilling through these barren intervals without circulation through the bit, the drill pipe might be stuck, since there would be no movement of fluid below the lowest oil sand penetrated. For this reason periodic testing was relied upon to furnish information as to productivity and presence of water.

Setting Liners

Perforated liners with 4¾-in. flush joints were landed in all wells. The first well in which a liner was run had only 90 ft. of open hole, and the liner went to bottom without difficulty. The next well had 347 ft. of open hole, and in the first two attempts to run the liner the 4¾-in. stopped on bridges. A diamond point bit was attached to the bottom of the liner and 2-in. washpipe and pack-off assembly placed inside the liner, so that fluid could be circulated through the bit, and with this arrangement the liner was successfully run to bottom. This became standard practice on all wells, although in some the liners went to bottom without circulating or rotating.

Completion of Well

After the liner is landed, the tubing is hung at the desired depth, the pump started, and gas injected. The pump is slowed down as the gas rate is increased. Finally, the pump is completely stopped and the well is brought in on gas lift through the casing. If the well pressure is sufficiently high, the gas is finally shut off and the well allowed to flow naturally.

Summary of Operations

Pressure drilling with the use of oil and injected gas as circulating fluid has been used at 14 wells. Of these, 12 were placed on production; pressure drilling was abandoned at one well after a caving shale bed had been drilled through, and one well was deepened and completed with mud after the zone drilled with oil had been tested and found to be wet.

In the 14 wells, 4088 ft. of hole was drilled, of which 3963 ft. was 5⅝-in. and the remaining 125 ft. was 8½ in. In drilling the 5⅝-in. hole, an average of 63 ft. was drilled with each bit, at an average rate of 5.63 ft. per hour. In one well in which more than 500 ft. of 5⅝-in. hole was drilled with mud, the corresponding averages were 31 ft. per bit and 4.2 ft. per hour. Only 53 ft. of hole has been cored with oil. Average rate while coring was 3.3 ft. per hour. The maximum amount of hole drilled in any well was 463 ft., and the minimum 90 feet.

No unusual difficulties were encountered in nine of the wells drilled. The remaining five wells experienced serious trouble with bridging and caving of the hole, which was the cause of considerable lost time. At one of these five wells, a string of drill pipe was stuck, and 23 days were consumed in fishing and sidetracking.

A consideration of this summary leads to the conclusion that it is possible to drill and complete wells at Kettleman Hills by this method of pressure drilling, with no more trouble than is to be expected when drilling with mud.

Comparison of Production Rates

Evaluation of comparative production data is difficult because the mechanical conditions, method of producing, gas-oil ratio, bottom-hole pressure, amount of producing formation and character of the producing formations vary from well to well.

In the comparison of initial production rates of wells drilled with oil with those of wells drilled with mud, wells were chosen in the same area, at the same structural position, and with all other conditions as nearly

TABLE 1.—*Comparison of Production Data for Wells Completed with Oil and Wells Completed with Mud*

Comparison	Well No.	Drilled with	Zone	Open Hole, Ft.	Maximum Daily Production										Bottom-hole Pressure Data						Remarks
					Date Completed	Net Oil, Bbl.	Free Water, Bbl.	Formation Gas, Cu. Ft. per Day	Circulating Gas, Cu. Ft. per Day	Cut, Per Cent	Gravity, Deg.	Tubing Pressure	Casing Pressure	Bean	Date	Shut in Pressure Mid-point of Perforations	Oil Rate, Bbl. per Day	Productivity Factor[c]		Gas-oil Ratio, Cu. Ft. per Bbl.	
																		Oil	Oil and Water		
I	I-A	Oil	III	90	5-12-36	1,726		4,000	None	20.0	28.4	560	50	1-C 128/64	5-25-36	1,390	726	0.92	1.06	2,787	
	I-B	Mud	III	92	3-9-36[a] 4-28-36	414 151		640 372	None None	0.4 2.0	34.7 34.1	20–60 8	Packer 340	1-T 128/64	3- 9-36	1,255[a]	452	5.08		1,400	
II	II-A	Oil	V	347	7-24-36	3,150		4,650	None	5.0	34.7	480	200	1-C 160/64	8-12-36	1,230	1,150	8.85		1,706	
															11-22-36	1,120	1,300	8.66		1,478	
															11-25-36	1,120	690	6.27		1,703	
	II-B	Oil	V	437	1-10-37	3,854		2,501	837	0.1	32.8	670	100	1-C 128/64		1,490[b]					No determination of productivity factor
	II-C	Mud	Upper 3/4 of V	251	5- 5-36	2,560		4,550	None	0.2	34.2	100	110	1-C 128/64	5-10-36	1,375	1,504	8.14		1,278	
														1-T 128/64	11-22-36	1,120	599	6.66		1,754	
III	III-A	Oil	V	463	8- 7-36	1,969		1,863	277	0.3	35.6	140	840	1-T 128/64	9- 8-36	1,200	1,302	18.6		1,140	
															9-12-36	1,200	568	10.3		1,324	
															12- 9-36	1,170	1,139	8.2		517	
	III-B	Mud	Test on V	Open perf. 424	4-14-36	1,195	18	8,130	None	0.2	38.0	460	960		4-16-36	1,124	1,310	5.1		5,280	
IV	IV-A	Oil	Lower 3/4 of III	135	9-10-36	1,643		1,061	1,258	0.2	37.0	160	720	1-T 112/64	9-13-36	1,050	1,607	11–5		732	
															1-20-37	1,025	1,426	4.52		627	
	IV-B	Mud	Lower 2/3 of III	112	5-11-36	1,364		1,053	648	0.2	36.6	115	600	1-T 128/64	5-14-36	1,090	1,360	3.89		770	
															9- 9-36	995	979	4.55		2,170	
															2- 6-37	855	828	2.76		3,717	
V	V-A	Oil	V	428	12-10-36	1,269	11	1,421	735	0.4	36.3	485	145	1-C 128/64	12-15-36	1,170	1,069	2.14		1,240	
															12-17-36	1,170	1,111	2.36		1,150	
															12-19-36	1,170	428	1.71		1,425	
	V-B	Mud	Top 1/5 Lower 7/10 V	461	4-20-36	1,836	9	1,534	?			150	925		4-22-36	1,380	1,863	7.45		840	
															4-24-36	1,380	980	5.60		718	
VI	VI-A	Oil	Lower 2/3 of V	311	1-30-37	681		1,318	1,552	0.2	38.2	440	160	1-C 128/64	2- 3-37	1,145	455	0.72		1,021	
	VI-B	Mud	Lower 5/8 of V	310	5-10-36	576	10	1,228	None			125	Packed off								No pressure data since setting packer above lower 5/8 of zone V
VII	VII-A	Oil	V	331	5-30-37	1,863	2	2,824	None		35.1	135–160	590	1-T 128/64	7- 7-37	1,105	1,520	5.5		1,462	
	VII-B	Oil	V	336	3-30-37	1,530	1	2,583	None		35.8	160	670	1-T 128/64		(Data not available)					
	VII-C	Mud	Zone V and top finger of Zone IV	315	7- 6-37	1,050		2,005	None	0.5	34.4	125	750	1-T 128/64		1,110	978	1.95		2,296	

[a] This production rate obtained during test prior completion of well.

[b] The first bottom-hole pressure reading after completion was 1610 lb., but this is considered to be in error.

[c] Barrels per day per pound drop of pressure at mid-point of perforations.

the same as possible. Table 1 shows the comparative initial production rates of wells drilled with oil and wells drilled with mud, together with all pertinent data as to conditions under which the wells were produced, bottom-hole pressures, amount of open hole, etc. Except in one instance the well drilled with mud was completed before the well with which it is compared. Nine wells drilled with oil and seven wells drilled with mud are used. The average production rates, shut-in bottom-hole pressures, gas-oil ratios, productivity factors, and amounts of hole open to production of the two groups of wells are as follows:

	Wells Drilled with Oil	Wells Drilled with Mud
Production rate, bbl. per day	1965	1279
Shut-in pressures at mid-point of perforations, lb. per sq. in.	1222	1222
Productivity factor	6.90	5.10
Gas-oil ratio, cu. ft. per bbl	2466	2734
Hole open to production, ft	320	280

Of the nine wells drilled with oil, five were produced on the gas lift, while only two of the wells drilled with mud were so produced. However, comparison of average rates of flowing wells shows a greater advantage for wells drilled with oil than does comparison of the average rates of the two groups as a whole:

	Flowing Wells, Bbl. per Day	Gas-lift Wells, Bbl. per Day
Average production, wells drilled with oil	2067	1883
Average production, wells drilled with mud	1159	1600

Three wells drilled with oil have been omitted from the comparisons; two because no near-by wells in the same zone were drilled with mud within the two years prior to their completion. In the third well, only the lower portion of the zone produced was drilled with oil. Average production of these three wells was 1715 bbl. per day, and their inclusion in the computation of average initial production would have reduced the rate from 1965 to 1902 bbl. per day for wells drilled with oil.

It seems reasonable to consider that the higher value of the productivity factor for wells drilled with oil is a result of the method used in drilling, because it is generally conceded that the presence of water and mud in the sand increases resistance to the flow of gas and oil.

The average amount of open hole is 14.3 per cent greater for the wells drilled with oil than for the wells drilled with mud. However, since the advantage in production rates is 53.6 per cent, it cannot be accounted for by the difference in average amount of open hole.

Further study of production data as the wells continue to produce will be necessary to determine whether wells drilled under pressure with oil will yield greater ultimate production than those drilled with mud.

It is reasonable to expect that the advantage of drilling under pressure with oil and injected gas will become more pronounced as formation pressures continue to decline.

DISCUSSION

(*W. H. Geis presiding*)

MEMBER.—What sort of results did you have with coring?

R. WINTERBURN.—Approximately 53 ft. of hole was cored; we had probably 25 to 30 per cent recovery.

MEMBER.—Did you have any difficulty in losing oil and gas in the formation during drilling and, if so, how did you overcome it?

R. WINTERBURN.—We had no evidence of the formation taking fluid. There was some loss from the system but most of this probably occurred while making round trips.

MEMBER.—I assume that your petroleum production figures are obtained a few days after the well is completed?

R. WINTERBURN.—Yes, one or two days after the well was completed. The productivity figure was secured, in most cases, shortly after the well was completed. The productivity factor as determined does not take into account the volume of gas produced and is therefore somewhat misleading for high-ratio wells.

MEMBER.—Did you have trouble in landing your liner with the modern knowledge of oil drilling?

R. WINTERBURN.—All the liners were landed successfully although sometimes it was necessary to circulate and rotate through bridges.

Desalting Crude Oils

By Gustav Egloff,* Member A.I.M.E., Edwin F. Nelson,* C. D. Maxutov* and Charles Wirth III*

(Oklahoma City Meeting, October, 1937)

The treatment of emulsified crude oils has been a problem for years in the petroleum industry. Until comparatively recently various methods of settling with and without chemicals have been used with indifferent success. Since wells have been acidized, emulsified crudes have been produced, which add considerably to the need for improved methods of treatment. The presence of large quantities of salts in the oils from acidized wells has presented several new problems to the industry. The use of hydrochloric acid in well treatments has caused the formation of sodium, magnesium, and calcium chlorides by interaction with the dolomitic limestones. These salts dissolve readily in the water normally present in the oil, and they are therefore incorporated in the emulsified oil. The crystalline salts have also been found in the oil, prevented from settling by protective films such as asphalt, resins and petrolatum. In some instances, free hydrochloric acid has been found. The salts may be present in crude oil in amounts ranging from a few pounds to over 1000 lb. per 1000 bbl. of oil.

The transportation of these crude oils through pipe lines has led to erosive and corrosive effects, which are a tremendous cost to the petroleum industry. During 1937, more than 1,200,000,000 bbl. of crude oil was transported through pipe lines. Of this quantity approximately 10,000,000 bbl. was water, and considerably more than 50,000,000 lb. was salts. If the crude oils were treated at the producing wells to remove the salts and water, an appreciable saving would be possible. The treatment would not be difficult, since it has been found that these oils are more easily treated at the time they are produced than after the aging and more stable emulsification that occur before they reach the refinery. Since great costs are involved in the use of these salty crudes at the refinery, treated oils essentially free of salts would naturally command a premium.

The real added costs lie in refining salt-containing crude oils. Severe corrosion of refinery equipment in both topping and cracking installations has appeared in many refineries. Chemicals such as ammonia, lime and

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* Universal Oil Products Co., Chicago, Ill.

caustic have been used to advantage but at great expense. The corrosion is most evident in preheat exchangers, crude still tubes, cracking coils, fractionating towers and condenser equipment. In addition, deposition of the salts throughout various sections of the equipment has caused a loss of efficiency and frequent shut-down periods. The loss of on-stream time has in some instances been particularly acute. The quality of the products from salty crude oils has been affected, especially in residual fuel oil and asphalt.

A number of explanations have been given for the high corrosiveness of these salty crudes. The calcium and magnesium chlorides are known to hydrolyze readily to form hydrochloric acid and the acid formed in this manner together with that present in the crude is believed to cause the excessive corrosion. In addition, some chlorinated hydrocarbons may be formed during acidizing, which under topping or cracking conditions decompose to yield corrosive products. Corrosion in high-temperature regions has been usually attributed to sulphur and its compounds, while hydrochloric acid and its salts were held responsible for corrosion in the condensing sections. However, all of the available evidence indicates that corrosion in high-temperature zones is considerably aggravated by the presence of hydrochloric acid or salts that may produce it by hydrolysis or decomposition. This idea is well illustrated by the data of R. E. Puckett[1] in which he rules out sulphur or its compounds as the sole cause. He assigns the major responsibility for the high corrosion to free acid and its salts, based essentially on analyses of the corrosion products. He suggests the possibility of an oxidation-reduction cell due to the presence of salts as accelerating the corrosion. The action of the acid upon iron sulphide with liberation of hydrogen sulphide to cause further damage may be an important factor.

We have theorized somewhat regarding the accelerated corrosion encountered in cracking-still tubes. The hydrated salts of calcium and magnesium chlorides probably melt in their own water of crystallization and hydrolyze, generating hydrochloric acid. This acid will be very corrosive at the high temperatures encountered since the water exists in the liquid phase because of its low vapor pressure and the comparatively high existing pressure on the system. If this hydrolysis went to completion, we might expect to find considerable percentages of calcium and magnesium sulphides as well as iron chloride present in the coke from the tubes. Some analyses have shown this to be true.

Some evidence has been obtained which indicates that the presence of chlorides or hydrochloric acid appreciably affects the formation of hydrogen sulphide. In a commercial cracking installation a Michigan topped crude was charged to the furnace tubes containing approximately

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[1] References are at the end of the paper.

150 lb. of salt per 1000 bbl. The gas produced from this charge contained 1100 to 1200 grains of hydrogen sulphide per 100 cu. ft., and severe corrosion throughout the unit was evident. With the installation of a settler for the removal of salt, the salt content of the charge was reduced to 40 to 60 lb. per 1000 bbl. The hydrogen sulphide content of the gas was reduced to approximately 400 grains per 100 cu. ft. It is possible that the salts or the acid may have a catalytic effect upon the decomposition of the sulphur compounds. No direct evidence of this action has as yet been obtained.

In order to emphasize the importance of the problem, salt analyses of typical crude and topped crude oils from various and numerous sources are shown. In Table 1, the salt contents of crude oils reach a figure as high as 780 lb. per 1000 bbl. The oils are representative of almost every section of the country. Similar data are presented for topped crude oils. The relative amounts of calcium and magnesium chlorides compared to sodium chloride are interesting.

Crude oils and topped crude oils used as cracking stock from various oil fields were analyzed for their salt content, the data of which are shown in Table 1.

Many processes have been proposed to dehydrate and desalt crude oils and a few have gone into commercial use. The properties of emulsified and salty crudes vary widely as to their amenability to treatment. No one method is most economic for all crudes. In some cases a combination of methods is used. A few of the commercial processes will be discussed here, such as: (1) heat and pressure, (2) chemical, (3) electrical, (4) centrifugal, (5) filtration.

SALT REMOVAL AT HIGH TEMPERATURE, PRESSURE AND ADDITION OF WATER

Laboratory Study.—A laboratory study of the effect of temperature, pressure, percentage of water added, emulsification and conditions of mixing of water and oil, depth of settling, and time of settling was made on a Mid-Continent topped crude. Twenty-six runs were carried out, covering the temperature range from 150° to 400° F., pressure from 50 to 300 lb. per sq. in., agitation time from ½ to 4 hr., settling time from 15 min. to 24 hr., and water added from 2 to 20.5 per cent by volume. One run was also made in which the gravity of water was increased by the addition of a small amount of salt in order to emphasize the gravity separation. In every run all the conditions were kept constant except the one whose effect was being studied.

Agitation.—It has been found that a definite degree of agitation should be obtained in order to bring about an intimate contact between water and salt particles. When and if agitation is carried too far, there may be danger of dispersing water in extremely fine globules throughout the body

TABLE 1.—*Summary of Inorganic Analyses on Crudes and Cracking Stocks*

Location	Type	Pounds per 1000 Bbl.			
		$CaCl_2$	$MgCl_2$	NaCl	All Cl as NaCl
Pennsylvania	Crude	Tr.	Tr.	Tr.	Tr.
Michigan	Crude	17.3	4.5	None	2.2
	Crude				187.0
	Crude	neg.	neg.		25.0
	Crude	tr.	tr.		25.0
				Average	59.8
	Topped crude				174.0
Kentucky	Crude				44.0
	Crude	17	15	58	90.0
	Crude	neg.	neg.		13.5
	Crude	104	11.2	204	318.0
	Crude	17	15.0	17	54.0
				Average	107.4
	Topped crude				85.0
	Topped crude				66.0
					97.0
		17	14	16	51.0
				Average	74.8
Kansas	Crude	38.1	6.7	46.0	91.0
					92.0
Arkansas	Crude	34.6	1.5	44	80.0
Mid-Continent	Crude				176.0
	Crude				138.0
	Crude	7	26	74	102.0
	Crude				73.0
					54.0
				Average	108.6
	Topped crude[a]	42	7	117	168.0
	Topped crude	34	4	145	185.0
	Topped crude	6	3	49	58.0
	Topped crude	26.0	2.2	16.0	43.4
				Average	96.8
Texas East Texas	Crude	19	tr.	None	2.2
	Crude				38.0
	Crude				13.0
				Average	17.7

[a] 25 other topped crudes showed salt contents ranging from 42.0 to 148.0 lb. per 1000 bbl.

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TABLE 1.—(*Continued*)

Location	Type	Pounds per 1000 Bbl.			
		$CaCl_2$	$MgCl_2$	NaCl	All Cl as NaCl
Texas (*Continued*)					
West Texas	Topped crude	48.5	6.7	48	103.0
S & W	Topped crude				107.0
				Average	105.0
	Crude				0.0
	Crude				445.0
	Crude				273.0
	Crude				0.0
	Crude				0.6
	Crude				0.0
	Crude				3.2
				Average	103.1
New Mexico	Crude				0.0
	Topped crude				35.0
Montana	Crude				37.0
	Crude				368.0
	Crude				152.0
	Crude				0.0
	Crude	32.9	9	None	36.6
				Average	118.7
Wyoming	Crude				0.0
Oregon	Crude	Neg.	Neg.		7.4
California	Crude	15.6	tr.	None	0.8
	Crude	27.7	7.5	25	60.6
	Crude				10.0
	Crude				0.0
	Crude				44.0
	Crude				0.0
	Crude				0.0
	Crude				2.5
				Average	15.0
Argentina	Crude	52.0	3.7	704	764.0
	Crude				797.0
				Average	780.5
Persian	Crude	Tr.	Neg.		260.0
	Topped crude	Neg.	Neg.	Neg.	Neg.
Russian	Crude	tr.	tr.		73.2

of oil and it may result in stabilization of the emulsion formed. As a consequence, a very poor separation of oil-free water will be obtained on settling, with the formation of an emulsion layer varying in thickness, percentage of water and salt, depending on the conditions. This layer lies between the desalted oil and the oil-free water. Furthermore, the desalted oil will have a much higher water content than if agitation were not carried so far.

Settling.—The amount of salt water withdrawn from the bottom draw-off increases with the increase of settling time, and the concentration of salt in it at first increases, then decreases. When the oil-free water was withdrawn at various time intervals, the concentration of salt in it reached the highest value after 30 min. of settling. Then it declined slowly and finally attained a constant value. This fact indicates that the water globules, carrying higher salt contents, coalesced in a relatively short time, followed by the globules of lower salt concentrations. The amount of water withdrawn from the bottom per interval of settling time reached its highest value after 2 hr. of settling at the conditions of 400° F. and 300 lb. pressure. At conditions of 200° F. and 50 lb. pressure, such poor separation of oil-free water was obtained that the effects described above could not be determined.

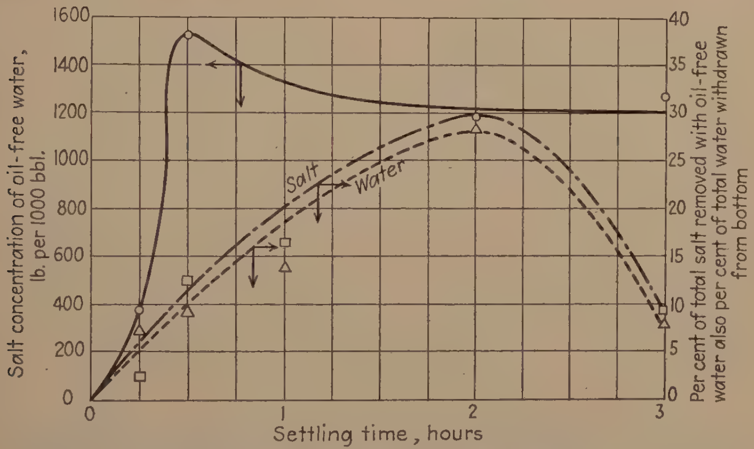

FIG. 1.—PERCENTAGE OF SALT REMOVED WITH OIL-FREE WATER AND AMOUNT OF WATER WITHDRAWN FROM BOTTOM.

The percentage of total salt in the oil-free water and the amount of oil-free water per time interval are plotted on Fig. 1 for 400° F. and 300 lb. pressure. The percentages of water and salt in the desalted oil decreases with the increase in settling time. At low temperatures the percentage of water seems to decrease more rapidly than the percentage of salt. This indicates that the salt was not completely dissolved in water because of low temperature, which did not affect the asphaltic or paraffinic films surrounding the salt crystals. At higher temperature this effect is reversed—that is, the percentage of salt decreases more rapidly than the percentage of water on account of the absence of films surrounding the salt crystals. In such cases the salt-concentration curve falls rapidly, with a tendency to become asymptotic to the horizontal axis at a certain value determined by the nature of the emulsion. Little evidence of stratification was found in the body of settled oil, the water and salt being rather evenly distributed with a tendency toward slightly higher salt concentrations in the upper layers.

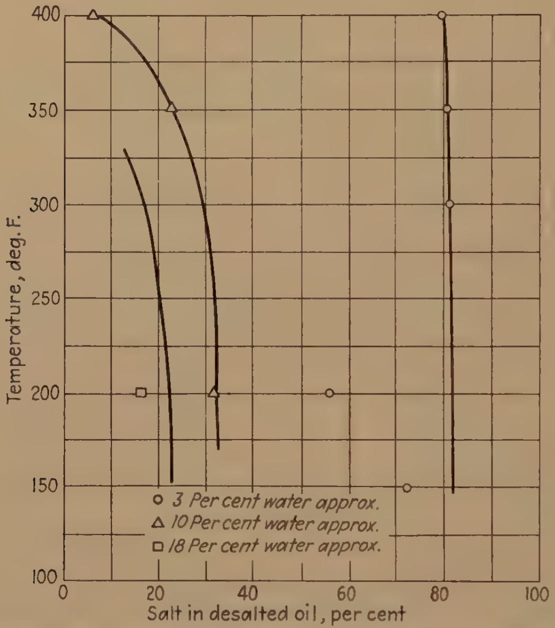

FIG. 2.—PERCENTAGE OF SALT IN DESALTED OIL AT DIFFERENT TEMPERATURES.

EFFECTS OF TEMPERATURE, PERCENTAGE OF WATER ADDED, AND PRESSURE ON SALT REMOVAL

The effects of temperature and percentage of water added on salt removal are very closely interwoven. When either factor is increased the salt content of the oil is decreased. Thus, to obtain a desired degree of desalting the temperature may be increased and the water decreased, or vice versa. From Figs. 2 and 3, it appears that the optimum amount of water added is 10 per cent by volume of oil, and the optimum temperature is 400° F. That is, if a definite weight of salt is removed at 400° F. and 10 per cent water, much higher temperatures must be used with 3 per cent of water to obtain the same desalting effect. At temperatures above 500° F., the critical conditions for water will be approached, while amounts of water higher than 10 per cent added to it will result in the formation of a much thicker emulsion layer, which tends to retain brine or water globules on its surface. Thus, the percentage of salt in oil-free water withdrawn from the bottom increases with an increase in temperature, while the percentage of salt in the emulsion layer (based on total salt content) and the emulsion layer itself decrease with an increase in temperature. As a rule, there is a better and sharper separation of water from the emulsion layer at higher temperatures, especially when between 3 and 10 per cent of water is used, yet no separation is obtained at 200° F. with 10 per cent of water. In general, the separation is poorest at 200° F. and best at 400° F. On the other hand, the temperature alone cannot control the amount of water in the desalted oil, as well as the behavior of an emulsion layer under various conditions of temperature and percentage of water added, without considering such an important factor as agitation. It is quite evident that the emulsion layer results from separation of a more stable emulsion in one layer, which cannot be broken under the conditions suitable for breaking a less stable emulsion (Table 2).

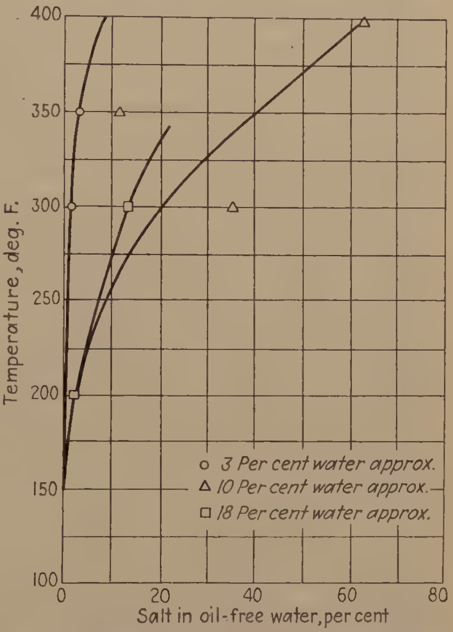

FIG. 3.—PERCENTAGE OF SALT IN OIL-FREE WATER AT DIFFERENT TEMPERATURES.

The pressure has no effect on breaking the emulsions and therefore the salt removal, providing it is kept higher than the vaporization pressure of water at the temperature. Comparing the two following runs, in which the conditions under which the emulsions were treated were identical with the exception of pressure (275 lb. and 160 lb. per sq. in., respectively), it was found that the change in pressure affected neither demulsification nor the salt removal.

Agitation Time, Hr.	Settling Time, Hr.	Pressure, Lb. per Sq. In.	Bottom Settlings and Water in Settled Oil, Per Cent	Salt Concentration, Lb. per 1000 Bbl.	
				Topped Crude	Desalted Oil
1	1	160	2.0	116	20
1	1	275	2.0	116	25

To summarize, the desalting is more effective at higher temperatures, about 400° F., with enough pressure to keep water in liquid form, about 300 lb. per sq. in., and approximately 10 per cent of water properly emulsified in oil. In these conditions, smaller emulsion layers are obtained (3 to 4 per cent of the total charge) with a very sharp separation of oil-free water.

TABLE 2.—*Conditions Leading to Emulsion Layer*

Temperature, Deg. F.	Pressure, Lb. per Sq. In.	Agitation Time, Hr.	Settling Time, Hr.	H_2O Added (by Vol.), Per Cent	H_2O in Settled Oil (Based on (Oil), Per Cent	Salt in Desalted Oil (Analysis), Per Cent	Salt Removed, Excluding Emulsion Layer, Per Cent	H_2O in Emulsion Layer (Analysis), Per Cent
150	275	1.0	1.5	3.0	1.8	71.6	33.8	26
150	275	1.0	1.5	10.0	0.8	10.0	90.0	51
200	275	4.0	1.5	3.0	1.2	54.3	45.6	40.0
200	275	0.75	1.5	10.0	1.5	30.7	74.5	70.0
200	275	1.0	1.5	18.0	1.8	14.6	85.3	60.0
300	275	4.0	1.5	3.0	0.6	80.7	19.3	22.3
300	275	1.0	1.5	10.0	1.7	29.0	71.0	55.0
300	275	1.0	1.5	18.0	0.7	16.4	85.3	82.0
350	275	2.2	1.5	3.0	2.1	80.7	19.3	19.8
350	160	1.0	3.0	10.0	0.5	7.6	92.4	16.0
350	275	1.0	1.5	10.0	1.7	21.8	78.2	57
400	300	0.75	3.0	Emulsion	1.4	16.3	83.7	1.0
400	275	0.5	1.5	3.0	0.4	78.3	26.5	5.3
400	300	1.0	3.0	10.0	0.7	8.2	91.8	5.4
400	275	1.0	1.5	10.0	0.9	5.8	95.0	50.0
400	300	1.0(+)	3.0	7.3	0.8	11.8	88.2	23.0
200	50	0.75	24.0	3.0	0.3		67.5	30.0
300	175	1.25	1.5	10.0	0.8	16.1	83.8	
400	275	1.00	1.5	10.0	2.0	25.6	74.4	30.0
300	175	1.25	3.0	10.0	0.8	15.4	84.7	56.0

COMMERCIAL APPLICATION

One of the processes most widely used commercially for desalting crude oils is that of heat and pressure. The crude oil, which may have the salt dispersed through it in crystal or colloidal form, is treated with water to dissolve the salt and produce a synthetic emulsified crude oil, which is then subjected to heat and pressure. The percentage of water added and the temperature, pressure and time of settling vary widely as a function of the properties of the crude oil.

A unit desalting by heat and pressure,[2] operating on Michigan crude containing 220 lb. of salt, reduced the salt content to 8 lb. per 1000 bbl. The crude oil is thoroughly mixed with from 10 to 12 per cent of water, which dissolves the salt and forms an emulsion. The synthetic emulsified crude is raised to a temperature of 250° F. under about 60 lb. pressure as it flows through a heat exchanger and a heating coil to a settling tank where the water is withdrawn and the crude then fractionated to commercial products. This operation eliminated corrosion, particularly of the condensing equipment on the various side streams from the bubble tower.

Salt is appearing in greatest quantity on the northern, western and southern portions of the East Texas field, but is fairly general through the field.[2] It is claimed that if from 3 to 5 per cent of water is added to the petroleum to dissolve the salt, the brine settles out best at 220° to 240° F. with a pressure of at least 110 lb. on the settling drum. This drum must be large enough to allow 50 min. for the settling process in a continuous operation. The charge pump serves to mix the water with the oil and the mixture is discharged through heat exchanger or small auxiliary heating tubes into a diffuser pipe that enters the salt drum horizontally near the bottom. Satisfactory conditions of temperature and pressure vary with the particular crude oil and with other factors. Some of the conditions that have been reported as successful are: 150° F. atmospheric pressure, and 80 to 90 min. settling time; 130° F., atmospheric pressure, and 16 hr.; 250° F., 185 lb. pressure, and 60 to 90 min. If the oil contains more than 150 lb. of salt per 1000 bbl., the temperature and pressure applied must be higher. The salt content must be reduced below 5 lb. per 100 bbl. of oil.

By mixing fresh water with the pressure-still charging stock under very definite conditions, the Naph-Sol Refining Co.[3] has been able to reduce the salt content of the topped crude from 150 to 20 lb. per 1000 bbl. The number of days the cracking unit is on stream has been doubled. The desalting unit found application in the Naph-Sol plant especially because of the unusually heavy salt content of the crude. All of the crude comes from the local producing fields, particularly the Porter, Crystal and Midland areas.

The installation cost less than $2000 and consists essentially of a heat exchanger and horizontal separator. In operation, the fresh water enters the system at the suction side of the pressure-still charging pump. The volume of fresh water taken into the system depends upon the salt content of the oil but under normal operating conditions has ranged between 3 and 4 per cent of the volume of the oil charged. The oil and fresh water are mixed within the pump and additional mixing occurs in the heat exchanger.

The heat exchanger is of conventional fin-type design. It has not been found necessary to add any special mixing devices to the system to improve its operation. The exchanger receives its heat from a stream of cracked residuum from the cracking unit. The adequate volume of the hot residuum available enables the operator to hold an outlet temperature of 300° F. on the oil and water mixture leaving the exchanger.

From the exchanger, the oil and water enter the horizontal separating drum at its lower end, through a line set about 2 ft. off the bottom. From this end the drum slopes upward so that the opposite end is about 2 ft. higher, which provides for an accumulation of the water at the lower end; an excessive accumulation would be quickly identified, as the trycocks farther up along the base of the separator show water.

This separator, or settling drum, is 42 ft. long and 5 ft. in diameter. It is insulated with 3 in. of rock wool and weatherproofed asbestos sheeting. This enables the operator to maintain the temperature of 300° F. To avoid vaporization of the water, a back pressure of 165 to 175 lb. is maintained on the drum.

Chemical Method*

The presence of salts in a crude oil almost invariably means that the oil contains emulsified brine or "B.S." However, even in crudes that show a B.S. content well below pipe-line limits, the amount of salt carried in solution in the emulsified brine may be surprisingly high. For example, the brine accompanying some Michigan crudes has a specific gravity of 1.21 and a chloride content, calculated as sodium chloride, of about 1200 grams per gallon. An oil containing only 0.5 per cent of this brine would have a chloride content (as NaCl) of 550 lb. per 1000 barrels.

The desalting of pipe-line oil, then, actually depends upon the removal of the last few tenths of a per cent of emulsified brine. In general this may be done in one of two ways—either by treatment of the crude to reduce the emulsion content to nearly zero or by dispersing fresh water in the oil to coalesce with and drag out the brine particles. The first method, "superdehydration," is difficult to apply in practice. With any process of demulsification the rate of separation of the dispersed phase must depend upon the rate of collision of the dispersed particles and upon the rate of settling of these particles in the oil. The one per cent or less of emulsion contained in refinery stocks almost always consists of extremely fine droplets, which (often less than 10^{-4} cm. in diameter) settle very slowly, and since the total concentration of particles is low, the probability of collision and coalescence of particles to form larger droplets that will settle out is also very small. The amount of salt removed by this method is directly proportional to the decrease in "cut."

To get good desalting results with the second method it is necessary that the fresh water be dispersed in the oil in fine particles, so that they will remain in the oil long enough to coalesce with the droplets of emulsified brine. If a coarse dispersion is formed, greatly increased amounts of fresh water must be used to give efficient results and this requires a large settling space. However, with a fine dispersion, the rate of settling is very slow, and this also demands large settling space. Furthermore, when the added fresh water is dispersed in small particles, they become, with most oils, more or less permanently emulsified because of the adsorption at their surfaces of the emulsifying agents commonly occurring in the oil. In order to obtain a rapid and efficient desalting operation with a minimum amount of fresh water, it is necessary to break the emulsion so formed or to prevent its formation. The use of demulsifying chemicals added either to the fresh water before dispersion, or to the oil, or possibly to both the oil and the water, has proved to be an effective way of meeting this problem.

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* From Dr. Charles M. Blair, Jr., The Tretolite Co.

On first sight, it may appear that the proper demulsifying agent to be used in a desalting plant is the demulsifier that was used in the field to treat the crude to be desalted down to pipe-line requirements. However, this does not appear to be true. The choice of a proper chemical compound for demulsification depends upon the type of oil, the amount and composition of the water phase, the agitation obtainable after addition of the chemical reagent, the settling temperature, the settling space, etc. All of these factors are generally different in the refinery and in oil-field practice. Furthermore, refinery crude stocks often are composite samples from a number of fields and one chemical demulsifying agent must be found that works well on this composite material. As the demand for demulsifying chemicals for desalting processes increases, probably new compounds will become available, designed to be especially effective for use in connection with these refinery emulsions containing a major proportion of dispersed salt-free water, but which may have little effectiveness on the hard-water oil-field emulsions as produced.

Of the two methods of adding the chemical demulsifier, it has been found by experiment that less chemical usually is required when it is added to the water rather than to the oil. When added in this manner, the chemical is necessarily near the water-oil interface to which it must eventually be adsorbed to prevent undue stabilization of an emulsion. When added to the oil, considerable time is required for it to diffuse throughout the large volume to the water-oil interface. Some of the most effective chemical compounds are not dispersible in water, and must necessarily be added to the oil. Also, as mentioned above, it may be desirable to add a demulsifier to both the oil and the water in some instances.

In explaining the effectiveness of the chemical method of desalting, it does not appear to be necessary to assume that the added fresh water is physically mixed with the salt water originally present, although this may occur to a small extent. It seems likely that some of the chemical demulsifier contained in the added fresh water (or in the oil) diffuses to the drops of emulsified salt water and in some manner counteracts the emulsifying agent there segregated, thus increasing the probability of coalescence of these drops with any other drops in which they may come in contact. Then too, the added fresh water increases the total concentration of particles and, as a result, greatly enhances the probability of collision of particles. These various factors, working together, result in the coalescence of many of the original salt-water droplets with fresh-water particles. Naturally, this process is repeated over and over until the droplets become large enough to settle rapidly and the concentration of dispersed phase falls back to low value. Optimum conditions for desalting would obtain if, in the dispersion formed, the particles of salt water originally present and the particles of added fresh water all happened to have the same size and the same probability of coalescence on contact with surrounding particles. Under such conditions, the amount of salt removed would be directly proportional to the ratio of volume concentration of added fresh water to volume concentration of brine originally present. This ideal condition cannot be reached in practice because of the impossibility of obtaining absolutely homogeneous dispersions and because the droplets of the dispersed brine may be coated with a stable, aged emulsifying layer, which prevents as complete destabilization of these droplets by the added chemical compound as is obtainable with the fresh-water droplets. The latter, from the moment of their dispersion in the oil, are prevented by the chemical reagent from forming a completely coherent emulsifying layer on their surfaces, consequently the tendency for fresh-water particles to coalesce with other fresh-water particles is somewhat greater than the tendency for fresh-water particles to coalesce with brine droplets. Although the conditions for optimum desalting cannot be completely reached, they may be approached very closely by proper adjustment of plant variables and correct choice of chemical demulsifier.

In localities where the amount of available fresh water is limited, it may be desirable to recycle the water effluent from the settling tank, using it a second time for dispersion in the untreated pipe-line oil. When this is done, the amount of residual salt in the oil desalted with this water becomes approximately double that left in the oil treated with the original fresh water. If extremely good results are obtained with the fresh water the higher salt content obtained by recycling the water may still be within the limit desired. By using such a recycling process, larger volumes of water may be used in each extraction, thus giving better separation of phases without increasing the total amount of fresh water required.

It is evident that no one set of conditions can be prescribed that will fit all chemical desalting plants. The variables to be fixed depend greatly on the type of oil, the salt content, the availability of fresh water, the ease of disposal of salt water, the degree of salt removal desired, the temperatures available, etc. However, there are a few conditions that seem to be uniformly necessary for obtaining good results—i.e., (1) as fine and uniform a dispersion of the added water in the oil as is still compatible with the requirement of moderately rapid and complete settling out of the water; (2) high settling-tank temperature; (3) careful selection of the demulsifying chemical.

ELECTRICAL METHOD

The electrical process for desalting and dehydrating crudes is in wide commercial use. In this method water is added in quantities adjusted to the requirements of the crude oil and thoroughly mixed to dissolve the salt, forming an emulsion. The emulsion is subjected to an alternating current of high potential, 16,000 to 33,000 volts. A typical installation,[4] at the Lion Oil Refining Company's plant, is desalting a particularly corrosive crude from the Urbana Arkansas field.

> Electrical desalting is accomplished in two steps. An emulsion is made of the salt-bearing crude and fresh water; then the mixture is electrically demulsified and separated. About 90 per cent of the salt is transferred from the crude oil to the water wash. Efficiency of salt removal depends upon the nature of the crude, degree of emulsification, and effectiveness of separation of oil and wash water. Emulsification is accomplished by one or more of the following methods: turbulent flow of oil and water; orifice-plate mixers; centrifugal pumps and back-pressure valves. The oil and water are separated by electrical dehydrators like those used for natural crude-oil emulsions.
>
> The dehydrator consists of a 180-bbl., 25-lb. working pressure, 10 by 12-ft. tank; 220-volt control equipment; two hundred and twenty to sixteen 500-volt transformers mounted on top of the tank; and electrodes within the tank. Average throughput per day per unit is 1500 bbl.; operating temperatures, 130° to 200° F.; electric power load, 2 kw.; amount of wash water, 5 to 20 per cent of the oil. The salt content is being reduced from approximately 200 lb. per 1000 bbl. to about 8 lb. per 1000 bbl. and dehydration occurs down to 0.7 per cent or less. Before desalting, the average length of a run on the crude unit was from three to six days, until a shutdown resulted from plugging of furnace tubes, exchangers and towers with solid salt. Corrosion of condenser and run-down equipment was severe. By using wash tanks, hot settling drums, and other schemes for reducing the salt content, runs were lengthened to 10 or 12 days. Since installing the electric desalters 60-day and 70-day runs are normal. During a typical operation, when the salt content of the crude was being reduced from 214 to 11.2 lb. per 1000 bbl., laboratory distillation showed that the release of hydrochloric acid at 650°F. was reduced from 63.85 to 0.54 lb. per 1000 bbl. of crude. The result is decreased corrosion of the equipment.[4]

In another refinery, the electrical desalting process operating on Kentucky crude contains from 0.5 to 1.0 per cent bottom settlings, or from 200 to 600 lb. of sodium, magnesium, and calcium chloride, which was reduced to about 20 lb. per 1000 bbl. of charge. The length of cracking-unit time on stream was thereby increased 300 per cent. The desalting operation improved the quality of asphalt, particularly as to solubility in carbon tetrachloride, from 99.5 to 99.95 per cent.

Similarly, when operating on a 40° gravity Michigan crude oil containing 120 grams of salt per barrel, which is made up largely of magnesium chloride, the corrosive effect on the unit was quite marked, not alone upon the distillation unit but upon the cracking unit also. When the crude oil was desalted electrically to about two grams per barrel, corrosion was reduced enormously and the cracking unit increased its on-stream time from 12 days to over 100 days.

It is reported by St. Hill and Eddy[5] that:

> Overall costs of the process have been found to range between 0.75 and 1.1¢ per barrel. These figures include a license fee, which varies with the amount of oil treated. A depreciation charge on the electrical desalting equipment is not included, because ownership of the units thus far installed had been retained by the licensing company. Plants now operating in the United States have demonstrated the applicability of the process in the successful treatment of a wide variety of oils from various Gulf Coast, Mid-Continent and Michigan fields. The specific gravities of these oils have ranged from 17.8° A.P.I. to as high as 40.0° A.P.I., and the salt contents from about 25 grams per barrel to over 200 grams per barrel. These salt contents are the equivalents of 55 and 440 lb. per 1000 bbl., respectively.
>
> The following table (Table 3) presents data obtained in connection with electrical desalting plants operating in American refineries.

TABLE 3.—*Data Obtained in American Electrical Desalting Plants*

Plant	Number of Desalting Units	Daily Through-put, Bbl.	Oil Gravity, Deg. A.P.I.	Salt Content, Grams per Bbl.		Water Used, Per Cent	Operating Temperature, Deg. F.	On-stream Time, Days Increased	
				In	Out			From	To
A	3	4,500	36	168	10	20	180	8	30
B	2	2,200	18	160	4	15	170	5	60
C	4	6,000	28	60	5	15	170		
D	2	2,500	40	150	5	20	190	12	48
E	4	6,000	39	25	3	20	190	7	24
F	2	2,500	26	137	6	8	140		

Centrifugal Action

The concentration of salt in Mid-Continent crudes and topped crudes show wide variations. This quantity varies in any given oil from summer to winter, since at higher temperatures much better separation of the salt takes place. The water present as an emulsion is quite small and the sediment ranges from 0.2 to 0.3 per cent. The oils in which the salt is dispersed may vary from nearly reduced Mid-Continent crudes of 20° A.P.I. with a viscosity of about 170 sec. Furol at 122° F. to crude oils of about 40° A.P.I. with a viscosity of approximately 40 sec. Universal at 100° F. As a more specific case, we had the problem of reducing the salt content of Mid-Continent topped crude cracking stock of 25° A.P.I. gravity with a viscosity of 22 sec. Furol at 122° F. from approximately 230 lb. to less than 30 lb. per 1000 barrels.

It is known that the salt present in oil may be in an emulsified brine or in crystalline form. Chlorine may be present in some organic chloride. The generalization can hardly be made concerning the amount of each variant present in oil, owing to the difference in nature and chemical composition of oils. While handling this problem we were enabled to get a more definite picture concerning the physical states of salt present in the sample of Mid-Continent topped crude and crude oil and also to observe its behavior under varying conditions. The investigations were carried out by the A.S.T.M. centrifuge method.

This method was especially valuable in determining the effectiveness of salt removal by centrifuging, the relative percentages of the crystalline and dissolved salt as emulsified brine in oil, and the advantage in centrifuging the crude oil instead of the topped crude with or without formation of synthetic emulsions prior to centrifuging.

Three samples of oil were used with gravities and salt content as follows:

Sample		A.P.I. Gravity	Salt, Lb. per 1000 Bbl.
1	Mid-Continent topped crude	25.7	116.0
2	Mid-Continent topped crude	24.3	150.3
3	Mid-Continent crude	39.9	63.5

All three samples with no water added were subjected to 2, 5, 10, 25 and 60 min. of centrifuging at room temperature, at constant speed of 1500 r.p.m. After the centrifuging period, the amount of bottom settlings and water was determined, oil above the B. S. & W. layer was decanted, and analyzed for salts, which were expressed as sodium chloride. Additionally, three oils were shaken with 5 per cent of water for 10 min. to form emulsions and then subjected to centrifuging for 5, 30 and 60 min., followed by the determination of B. S. & W. and the salt content in the decanted oil. Fig. 4 summarizes the obtained results.

It was noticed that when centrifuging topped crude and crude oil the salt content decreased more rapidly during the first 10 min. of centrifuging than during the next 50 min. The experiments show that such rapid decrease in salt is due to removal of the emulsified brine which separates as a lower layer. This is proved by the fact that there is no further increase of the B. S. & W. layer.

Later, when the water carrying salt is removed, the crystalline salt starts to settle out, reducing the salt content of the oil still further. But the removal of crystalline salt proceeds at a much slower rate because the salt particles are surrounded by hydrocarbons, whose viscosity offers the resistance to the salt crystals as they settle. Thus for the crude oil. which had a gravity of 15° A.P.I. higher, the percentage of salt removal was further ahead than that of the topped crude, which is shown by the slope of the respective curves on Fig. 1.

After 30 min. of centrifuging, the salt concentration is still decreasing without the increase in B. S. & W. layer. This indicates that part of the crystalline salt can be removed by centrifuging without being dissolved in water but at much slower rate. The general shape of the curves and the water analyses taken at time intervals suggest the presence of salt in three different forms: (1) brine, emulsified in oil; (2) crystalline salt that is affected by centrifuging; (3) crystalline salt that is but slightly affected by centrifuging. These forms of crystalline salt probably differ from each other in size of crystals or in colloidal form, and in the nature of the hydrocarbon film surrounding the crystals.

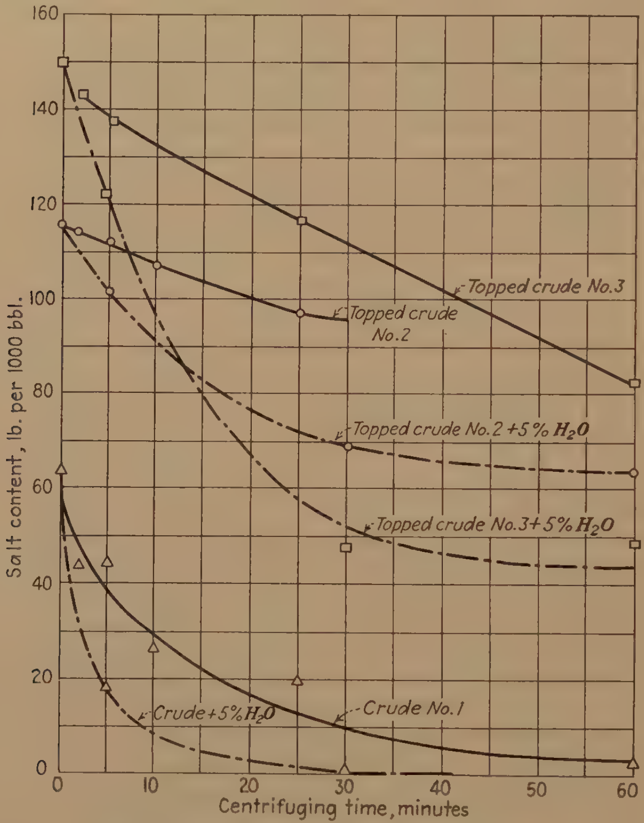

FIG. 4.—SALT REMOVAL BY CENTRIFUGING.

For these reasons it is desirable to have as much of the salt as possible in the form of an emulsified brine, which is readily removable by centrifuging, provided the emulsion is not stabilized. Thus when 5 per cent of water was emulsified, greater salt reduction resulted for the same centrifuging time than in centrifuging the corresponding "dry" samples. However, regardless of how much water was added, or how long the mixture was agitated, the salt content cannot be completely reduced unless the asphaltic or paraffinic film surrounding the salt crystal be removed and the crystal be brought into the intimate contact with water. Otherwise the time will be greatly increased with the removal of successively smaller and smaller crystals at successively slower and slower rates. The results of the tests are shown in Tables 4 and 5.

TABLE 4.—*Centrifuging with 5 Per Cent Water by Volume*

Sample	Sample No.	Centrifuging Time					
		5 Min.		30 Min.		60 Min.	
		A.S.T.M.		A.S.T.M.		A.S.T.M.	
		Salt, Lb. per M Bbl.	Water in Decanted Oil, Per Cent	Salt, Lb. per M Bbl.	Water in Decanted Oil, Per Cent	Salt, Lb. per M Bbl.	Water in Decanted Oil, Per Cent
Mid-Continent topped crude....	1	102.5	0.3	69.3	0.3	64.4	0.3
Mid-Continent topped crude....	2	122.0	0.5	47.8	0.0	48.8	0.0
Mid-Continent crude...........	3	18.6	tr.	1.0	0.0	tr.	0.0

TABLE 5.—*Centrifuging without Addition of Water*

Sample	Sample No.	Original B. S. & W. in Oil, Per Cent	A.P.I. Gravity	Salt Content, Lb. per M Bbl., on Centrifuging for:						A.S.T.M. Water in Decanted Oil after 60 Min. Centrifuging
				No Centrifuging	2 Min.	5 Min.	10 Min.	25 Min.	60 Min.	
Mid-Continent topped crude, per cent reduction in salt content........................	1	0.3	25.7	116.0	114.2	112.3	107.8	97.8		0.1
				0.0	1.5	3.2	7.1	15.7		
Mid-Continent topped crude, per cent reduction in salt content....................	2	1.0	24.3	150.3	142.6	132.0	138.0	116.3	82.3	tr.
				0.0	5.2	12.2	8.5	22.8	45.3	
Mid-Continent crude, per cent reduction in salt content.....	3	0.4	39.9	63.5	43.9	43.9	26.4	19.5	2.5	tr.
				0.0	30.8	30.8	58.4	69.3	96.0	

In view of these facts, it is self-suggestive that the closest contact between water and salt crystals may be obtained by: (1) proper and sufficient agitation, which should be determined separately for every individual case; (2) higher temperatures, which will reduce the viscosity of the oil as well as soften or melt down the film surrounding salt crystals. As a result of these considerations and the tests made with the cooperation of the Sharples Specialty Co., it was possible to obtain 99.7 per cent desalting of Mid-Continent topped crude by the centrifuging method.

A special type of centrifuge, similar to the one used for acid treating, can be employed for desalting crudes or topped crudes. For example, with such a centrifuge, the original salt content of 160 lb. per 1000 bbl. was reduced to 0.5 lb. per 1000 bbl. The centrifuge is equipped with a 5-hp. motor, runs at a constant speed of 15,000 r.p.m., and demands 2.3 kw. Prior to centrifuging, oil is mixed with about 10 per cent water, although the amount of water may be increased if necessary. The oil-water mixture is heated to not higher than 210° F., agitated for a predetermined length of time and charged to the centrifuge.

Thus an almost complete desalting by centrifuging method can be attained. However, such a degree of desalting is not necessary to suit the refining units, and it may be economical to sacrifice a certain degree of desalting for greater capacity or fewer centrifuges. On the other hand, it may be feasible to blend completely desalted oil to a desired salt content with salt-containing oil.

Filtration

Although this method of salt removal has not assumed commercial proportions, investigative work in our laboratories has indicated its feasibility. Satisfactory mechanical design of the filter equipment is at present the primary and perhaps only limitation. It is probable that a suitable method will eventually be realized, and this procedure without doubt will employ a filter aid. Without a filter aid, the impurities and salt in the oil will either pass through the filter cloth or completely clog and seal the flow channels. The primary functions of filter aids, according to Elsenbast and Horine[6] are as follows: (1) The removal of turbidity, suspended salt, wax, small amounts of moisture, etc., by incorporation in a filter-aid cake; (2) the surface-tension effect of breaking emulsions by passage through a filter-aid film; (3) protection of the cotton, wool or metal filter fabric. When petroleum emulsions are filtered through a filter aid, the emulsion is broken and the separation of oil and water in the filtrate occurs. Crude oils containing salts in either the solid or dissolved phase can be desalted.

Two sets of data were obtained in our laboratories using different laboratory apparatus. In the preliminary work, a hollow disk was used, one face of which was cloth supported on metal screening. An outlet on the other face was attached through a trap to a vacuum line. The filter-aid material was applied to this disk by immersing in naphtha in which the filtering material had been mixed. A cake ½ to ¾ in. thick was thus applied and held in place by the vacuum. The filter was immersed in the oil under test and the oil was sucked through into the trap. After each test a thin layer of the filter aid was scraped off, exposing a fresh surface. The results of some of the tests are tabulated in Table 6. The filtration in these tests was effective in reducing the salt content to a satisfactory figure.

TABLE 6.—*Filtration Tests*

Run No.	Type of Oil	Rate, C.C. per Min.	Water Separated, C.C.	Salt in Oil, Lb. per 1000 Bbl.	
				Before	After
1	Kentucky crude	140	Not measurable.	240	9.2
2	Kentucky crude + 10 per cent emulsified water	77	40[a]	240	29.2
3	Michigan topped crude at 200° F.	207	15	90	14.8

[a] 87 per cent of water added.

In a larger experiment with a small vacuum precoat filter, several tests were conducted to determine the salt removal and the filtration rates. A Mid-Continent topped crude oil containing approximately 100 lb. of salt per 1000 bbl. was used. The oil was maintained at a temperature of 130° to 290° F. in the several test runs. A vacuum of 5 in. of mercury was maintained during most of the tests. The filter-aid precoat was placed on the filter with the aid of a clean gas oil. Under these conditions filter rates as high as 30 gal. per sq. ft. per hour were reached. The results obtained showed a removal of salt to 14 lb. per 1000 bbl. Based upon a rate of 24 gal. per sq. ft. per hour, a filter of approximately 80 sq. ft. should filter 1000 bbl. in 24 hr. This sized installation is not unreasonable for commercial operation.

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Chapter II. Review of Notable New California Fields

The Wilmington Oil Field

By E. J. Bartosh*

(Los Angeles Meeting, October, 1937)

In the brief period from November 1936 to September 1937, the Wilmington oil field developed far beyond all expectations. Decline in some wells appears very rapid, but it is too early to draw definite conclusions, as the majority of wells are maintaining very large and steady output. Heavy curtailment in the central area, which has developed the largest wells, makes it impossible to arrive at a satisfactory estimate of decline.

The field is producing oil from the Repetto (lower Pliocene) and Puente (upper Miocene) formations, which are of the same age as formations producing at Torrance, El Segundo, del Rey or the marginal fields of the Los Angeles Basin. All of these fields are underlain by schist. The Long Beach field, northeast of Wilmington, is productive throughout 3000 ft. of Repetto-Pliocene series and also approximately 3000 ft. of Miocene formations, whereas at Wilmington only 700 to 800 ft. of Repetto and 2500 ft. of Miocene formations contain oil and gas.

This paper gives a brief summary of the history and development of the field to Sept. 15, 1937, showing the subsurface conditions as they exist with the field only partly developed.

History of Development

The Wilmington oil field, 20 miles due south of Los Angeles, adjacent to Los Angeles harbor and about midway between the cities of San Pedro and Long Beach (Fig. 7), was producing oil as early as 1932 and only came into prominence as a major oil field of Southern California in the fall of 1936, when the General Petroleum Corporation of California completed Terminal well No. 1 from the upper Miocene, at a depth of 3625 ft., for a daily production of 1500 bbl., 20° gravity A.P.I., thereby establishing discovery of the Terminal zone.

As early as 1925, or during the close of the development of Torrance oil field, a number of wells were drilled in the Main Street area looking for

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* Bankline Oil Co., Los Angeles, California.

possible extensions of the Torrance field. Most of these wells were definitely edge wells and low structurally with regard to both Torrance and Wilmington fields. From 1925 to 1932 a few wells were drilled southeast of this area and in January 1932, well A (Fig. 1) was completed on the pump at a depth of 3786 ft. in Repetto formation for an initial of 75 bbl. daily of 13.0° gravity oil, thereby establishing discovery of the Ranger zone. Subsequent drilling by various operators in wells indicated on

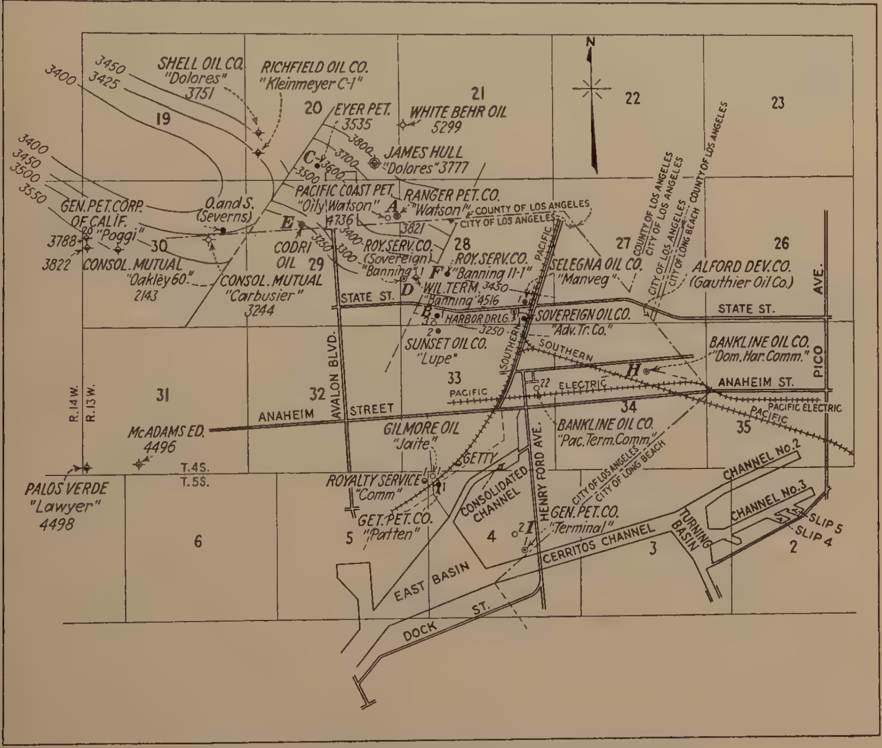

FIG. 1.—CONTOURS ON TOP OF RANGER ZONE.

Fig. 1 and Table 1 as B, C, D, E, F and G proved better production southeast of the original area, all producing oil from the Repetto (lower Pliocene), and H and I, drilled in 1936, definitely proved that a major field existed. Well G, completed June 11, 1936, in the upper portion of the Ranger zone for initial production of 195 bbl. daily of 17.4° gravity oil, well H for 125 bbl. daily of 16.0° gravity, in November 1936, and well I, in November 1936, for 1500 bbl. daily production from the Terminal zone (Miocene).

The discovery of the Tar and Terminal zones may be attributed directly to a structural interpretation of the area in which a seismograph may have played an important part. This well was higher structurally than any well previously drilled. The subsurface work on the early wells may be credited for the discovery and later development of the Ranger zone.

Subsequent work in the subdivided area in the northerly and westerly parts of the field precipitated a drilling campaign, which began in December 1936 and reached a boom period when major operators with large acreage began offset drilling. On May 12, 1937, in all 83 wells had been completed and 47 were drilling. By June 1 of that year 108 wells had been completed for a potential daily output of 65,985 bbl. Curtailment became effective on June 2 in the central part of the field, and production averages for July were 48,794 bbl. daily from 180 wells. This was a daily average of 271 bbl. per well.

TABLE 1.—*Drilling Record*

Well	Company	Well Name	Production Method	Initial Production, Bbl. per Day	Gravity	Date Completed	Total Depth, Ft.	Plug Depth, Ft.
A	Ranger Petroleum Co.	Watson No. 2	Pumping	75	13.0	1/26/32	3,821	3,786
B	(Chas. Baehr) Sunset Oil Co.	Lupie No. 1	Pumping	100	15.8	6/28/33	3,634	
C	Eyer Petroleum Co.	No. 1	Pumping	75	14.5	4/ 2/36	3,794	
D	(Sovereign Oil Corp.) Royalty Service Corp.	Banning No. 1	Pumping	150	15.0 4% cut	5/ 8/36	3,663	3,535
E	Codri Oil Co.	No. 1	Pumping	40	13.0 5% cut	8/14/36	3,901	3,540
F	Royalty Service Corp.	Banning No. 11-1	Pumping	100	13.0 3% cut	8/ 8/36	3,758	
G	Harbor Drilling Co.	No. 1	Pumping	195	17.4 5% cut	6/11/36	3,566	
H	Bankline Oil Co.	D. H. C. No. 5	Pumping	125	15.0 3% cut	11/ 5/36	4,337	3,507
I	General Petroleum Corp. of Calif.	Terminal No. 1	Flowing	1,440	20.0 3% cut	12/ 6/36	6,814	3,625

The development at this stage shows the general structural features determined by early drilling. The expectation of a rise in structure to the south and east was well founded because the present developed area extends beyond all previous conceptions of the field. The proven area now covers only the central, northerly and westerly portions of the structure, leaving the easterly and southeasterly portions unknown.

GEOLOGY

The surface formations are San Pedro-Quaternary sands and gravels varying in thickness from 500 to 700 ft. and lying unconformably upon the upper Pico-Pliocene formation. A columnar chart is given in Fig. 2.

The upper Pico rests unconformably upon the Repetto (lower Pliocene) in the highest part of the field, whereas on the north flank and low fault block the middle Pico member apparently is overlapped by the upper Pico, leaving an unconformable contact between the middle Pico brown shales and the Repetto. This unconformity is very noticeable in all electrical logs, particularly in the west and central areas, where a sharp break in the electrical curve, due to low resistivity, is discernible. Interpretation of these curves also indicates brackish water sediments down to this hiatus and that all sands below or in the Repetto not containing oil have a very saline water.

The Repetto (lower Pliocene) and upper Puente (Miocene) contact is normal. The upper Miocene is marked by the predominance of gray-white diatomaceous shale with thin partings of oil sands for the upper 100 ft., grading to platy and brown massive shales (commonly referred to as "poker chip" shale). Numerous hard calcareous or porcelaneous shales are found in the Miocene column. This Miocene section is fairly uniform from the contact down to the middle Miocene formation, which is encountered at 6425 ft. The middle Miocene formation continues on down to the top of the Franciscan (?) schist, which has been found at 6787 feet.

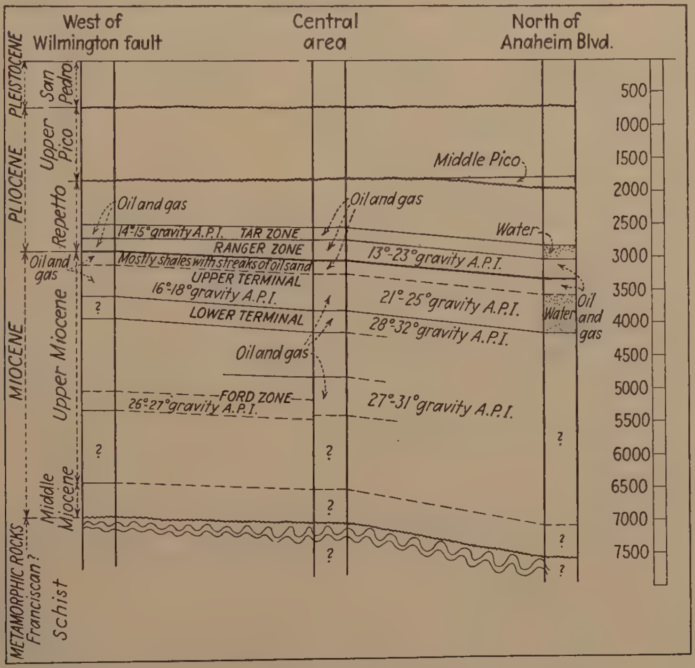

FIG. 2.—COLUMNAR SECTION, WILMINGTON OIL FIELD.

STRUCTURE

Topography of the area is very gentle and ranges in elevation from 10 to 40 ft. There was very little evidence of structure except in the slight elevation in surface east of the flood-control channel. All work was of subsurface nature before intensive drilling began and after discovery of Tar and Terminal zones.

Magnetic[1] and drill-pipe orientation of cores from some of the early wells aided materially in determining subsurface structural trends, and since the field has developed the results of these early magnetic orientations have been confirmed (Fig. 3). The field may be described as a faulted and irregularly shaped dome with major faulting transverse to principal axial trends.

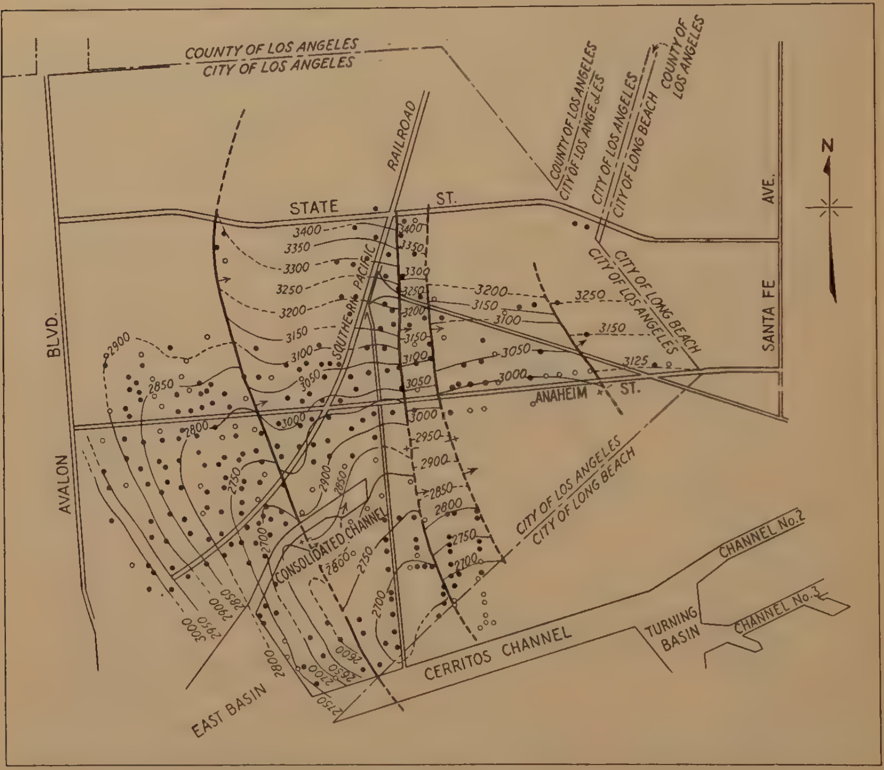

FIG. 3.—STRUCTURAL CONTOURS ON TOP OF RANGER ZONE (F).

Four normal faults are outlined by present development (Fig. 4):

1. In the westerly part of the field, the Wilmington fault, with a throw varying from 260 to 275 ft. measured at Miocene contact, has an average hade of 30° easterly. The hade of this fault decreases north of Anaheim Boulevard.

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[1] E. D. Lynton: Laboratory Orientation of Cores by Their Magnetic Polarity. Amer. Assn. Petr. Geol. *Bull.*, **21**, No. 5.

2 and 3. Two other parallel faults of less magnitude, with the same general trend, cut through the central part of the field east of Ford Avenue, and for discussion purposes will be referred to as the graben faults. The west fault hades 20° easterly with a throw of 30 to 60 ft., and the east fault also hades 20° easterly with a throw of 50 to 80 feet.

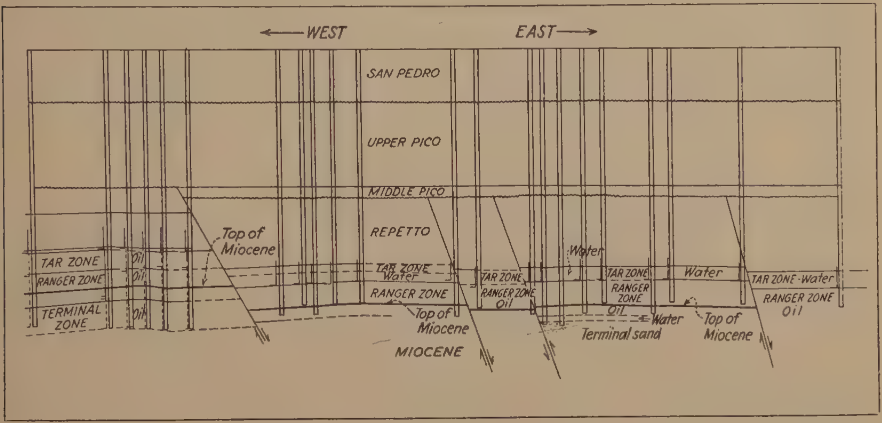

Fig. 4.—Producing zones and normal faults north of and parallel with Anaheim Street, Wilmington oil field.

4. The fourth fault, the farthest east, herein referred to as the Dominguez harbor fault, with beds upthrown on the west and downthrown on the east with a displacement of approximately 100 ft., hades about 15° easterly and leaves a large upthrow block on the north flank of the structure.

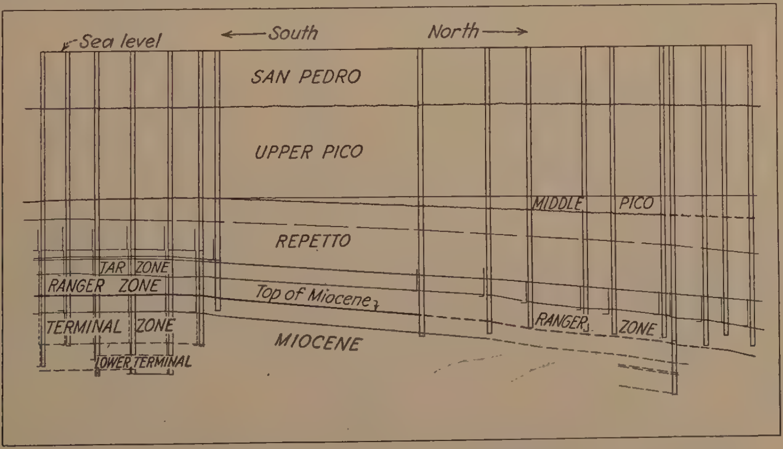

Fig. 5.—North-south cross section, Wilmington oil field.

The major faulting apparently occurred near the close of Miocene time. As determined from the detailed study of electrical logs, the Miocene stratigraphy appears very uniform.

The overlying Pliocene (Fig. 5) normal at the contact, shows considerable thickening of shales in the depressed areas and gradational increase in sands on the high portion of the fault blocks. There is also a progressive thickening of the sands to the north and at certain structural levels a large amount of carbonaceous material, also shore-line forms of megascopic fossils, which probably indicates a regressive sea during the period of deposition, owing to the progressive uplift of the region southwest of the area.

Oil and Gas Zones

Five producing zones have been proven (see Fig. 4):

1. The Tar zone (Repetto, lower Pliocene) ranges in depth from 2400 to 2800 ft., with a thickness of 225 to 350 ft. This contains an average of 95 ft. of oil sand, or approximately 33 per cent. The zone is marked by micaceous silts at the top, grading downward to fine and coarse oil sands. The initial productions of wells range from 195 to 325 bbl. per day of oil ranging from 12.5° to 15° A.P.I gravity. This oil has a gasoline content of 0.00 to 3.73 per cent and a sulphur content of 1.94 to 2.43 per cent.

2. The Ranger, or F, zone (Repetto, lower Pliocene) is encountered at depths of from 2600 to 3500 ft. with a thickness of 200 to 340 ft. It is marked by firm, clayey shales at the top with calcareous concretions in places, with abundance of micro fauna. The principal oil sands lie in the upper 200 ft. and grade from medium to coarse-grained oil sands to dense massive shales, with numerous thin lenses of fine oil sands in the lower part. The total oil sand is from 75 to 130 ft., or approximately 35 per cent of the zone. The oil in this zone ranges from 14.4° to 23.4° gravity A.P.I., and initial production varies from 50 to 3000 bbl. per day. The gasoline content ranges from 3.0 to 21.0 per cent, and the sulphur content from 1.22 to 2.20 per cent.

3. The top of the Upper Terminal, or H, zone (Puente formation, upper Miocene) is encountered 200 ft. below the Miocene contact at depths of 3050 to 3450 ft. Productive thickness of the zone varies from 40 to 600 ft. and consists of alternate sands and brown shales, approximately 50 per cent of the zone being oil sand. Initial production ranges from 300 to 2000 bbl. daily of 17.0° to 25.0° gravity oil. The lower-gravity oil is found in the area west of the Wilmington fault. The sulphur content varies, according to gravity, from 1.34 to 2.5 per cent, the lighter oil having the smaller amount of sulphur; and the gasoline content is from 7.60 to 17.65 per cent.

4. The Lower Terminal (Miocene) is encountered at depths of 3650 to 3800 ft. and has a thickness of 300 ft. with an initial production of 2500 bbl. daily of 27° to 31° gravity oil A.P.I. This zone also consists of about 50 per cent oil sand. The sulphur content is 0.89 per cent and the gasoline content is 34.0 per cent.

5. The Ford zone is encountered at 4800 to 5100 ft. with a thickness of 500 ft. and has an initial production of 500 to 700 bbl. daily of 31° gravity oil A.P.I. It also consists of about 50 per cent oil sand. The sulphur content is 0.81 per cent and the gasoline content 30.97 per cent.

In some parts of the field it is a common practice to produce the Tar and Ranger zones together, or the Ranger and Upper Terminal zones, or the Upper Terminal and Lower Terminal zones. This, of course, is done only where no intervening water is present.

The largest well to date is a combined Upper and Lower Terminal zone well, and has developed a potential production of 7700 bbl. per day of 30° gravity A.P.I. oil, with 3500 M cu. ft. of gas.

Unlike some of the major fields in the Los Angeles Basin, this field shows no high-pressure gas zones overlying the oil measures. The majority of the flowing wells yield a very low volume of gas at first and as the rate of withdrawal increases the volume also increases. The Ranger zone shows volumes of 50 to 550 M cu. ft. per day. Some of the Miocene zones have shown larger volumes of gas in the central area. These wells have developed volumes of 50 to 3500 M cu. ft. The gasoline content varies according to pressure and zones and is from 0.50 to 2.00 gal. per M cu. ft.

The probable proven acreage of each zone is: Tar zone, 1200 acres; Ranger zone, 2100; Upper Terminal zone, 1200; Lower Terminal zone, 500; Ford zone, 500.

DRILLING PROGRAM

City and State Regulatory Measures.—The portion of the field included in the City of Los Angeles is divided into light and heavy industrial zones. The light, or D zone, requires approval of zone change by the Planning Commission and City Council, together with signature of the mayor, and well derrick permit from the Board of Fire Commissioners, in addition to the well-known requirements of the State Division of Oil and Gas. The heavy, or E, zone is more simple and requires only approval by the Board of Fire Commissioners and compliance with State requirements.

Methods.—Drilling is done entirely by rotary method. Steam and gas engines and electric Hild drives are used. The drilling time to completion at depths of 3300 to 3600 ft. is 18 to 30 days. Most of the wells are drilled with fishtail bits; occasionally rock bits are used in drilling the hard calcareous members of the Ranger and Terminal zones.

Drilling is comparatively easy and no unusual hazards, such as high-pressure gas, caving shales or loss of circulation, have been encountered. The customary practice has been to drill a well to the Tar zone, then run an electrical survey, which has been one of the greatest aids in making subsurface correlations in this field, accompanied by micropaleontology, which has definitely established the principal marker horizons and thereby simplified correlations of the electrical logs. After the primary water string has been cemented, the well is drilled to what is considered a safe penetration in the oil zone and a second survey is made prior to landing of the oil string or liner and combination shutoff tests. The casing type of formation testers are used for the water shutoff tests.

The size of perforations in the oil string ranges from 30 to 80 mesh vertical slotted, although the majority of wells are completed with 80 mesh. There is no definite proof that the wells using larger casings have produced more oil to date. There may be a few exceptions to this statement, but undoubtedly the ultimate recovery of individual wells completed in the same structural position and in the same zone will be an important factor in this problem of larger casings.[2]

Cost of drilling wells ranges from $30,000 to $60,000 for average Ranger and Terminal zones, although in certain areas foundation and excavating or road building increases the cost considerably, as all piers and concrete corners must be set on piling, because the top soil is soft and soggy.

Casing Program

The casing program for different wells varies according to the different areas and type of oil zone encountered, as follows:

1. Typical Tar zone well:

   16, 18 or 20-in. conductor casing 90 to 150 ft.
   10¾, 11¾ or 13⅜-in. water string 2200 to 2600 ft.
   6⅝, 7, 8⅝ or 9-in. oil string 2500 to 2900 ft.

2. Typical Ranger zone well:

   13, 16, 18 or 20-in. conductor casing 90 to 700 ft.
   8⅝, 10¾ or 11¾-in. water string 2700 to 3600 ft.
   6⅝, 8⅝ or 9-in. oil string or liner 2900 to 3800 ft.

3. Typical Upper Terminal zone well:

   Conductor casing and primary water string same as for Tar zone well.
   6⅝, 8⅝ or 9-in. oil string or liner landed at 3600 ft. with combination shutoff at top of Terminal zone.

4. Lower Terminal zone well:

   Same as Upper Terminal except additional 4¾ or 5¾-in. liner or oil string down to about 4000 ft.

5. Ford zone well:

   Same as Terminal with additional oil string landed in bottom zone and combination shutoff at 4800 ft.

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[2] E. K. Parks: Selection of Sizes of Oil Strings in California. Amer. Petr. Inst. *Paper* 801 (1937).

PRODUCTION

Fig. 6 shows the production curves for the entire field. This graphic picture shows the rapid increase in the total number of wells in a period of six months, with the peak still an unknown quantity. On June 2, 1937, the average daily production per well was 463 bbl. Curtailment became effective on that date and, along with decline of early wells, showed a drop in this daily average to 269 bbl. by July 2, and a daily average per well of 230 bbl. on Sept. 1. This is an average daily decline per well of 29 per cent from June 2 to Sept. 1, and of 12 per cent from Aug. 1 to Sept. 1.

The majority of the wells have been completed as normal flowing wells, with the customary setting of tubing above the perforations and circulating with water until the well would start to flow. A few wells have required swabbing.

Sand is one of the problems in all oil wells, and this field is no exception, although conditions are worse in certain portions and may be attributed particularly to the character of the sands, especially the silty and micaceous members. In flowing wells by maintaining a uniform back pressure, very little sand trouble occurs. Sand trouble usually occurs when wells have ceased to flow or a disruption of the bottom-hole pressure begins to develop.

An interesting development in this field is the regular meeting of operators to discuss common production problems and seek remedies for combating them. I believe the consensus is that a careful check of fluid levels with the Depthograph and record of bottom-hole pressures, which are being made, will aid materially in determining the proper rate of withdrawal, thereby retarding the shifting and heaving of sands.

In a number of wells, tubing has been set with packers and has prolonged the flowing life of these wells. In certain areas it has been found more practical to pump wells before they have ceased flowing, but in these pumping wells a constant back pressure is maintained with special regulating valves. This regulating of back pressure and the rate of withdrawal appears to be a very satisfactory method in retarding the entry of sand into the well.

PIPE-LINE FACILITIES

General Petroleum Corporation of California and Richfield Oil Corporation are the only two pipe-line companies handling oil from this field. Practically all of the oil produced in the westerly area is shipped by truck to various refineries in the Los Angeles Basin.

The price of oil ranges from 40¢ to 80¢ per barrel, depending entirely upon the gravity and the purchasing companies.

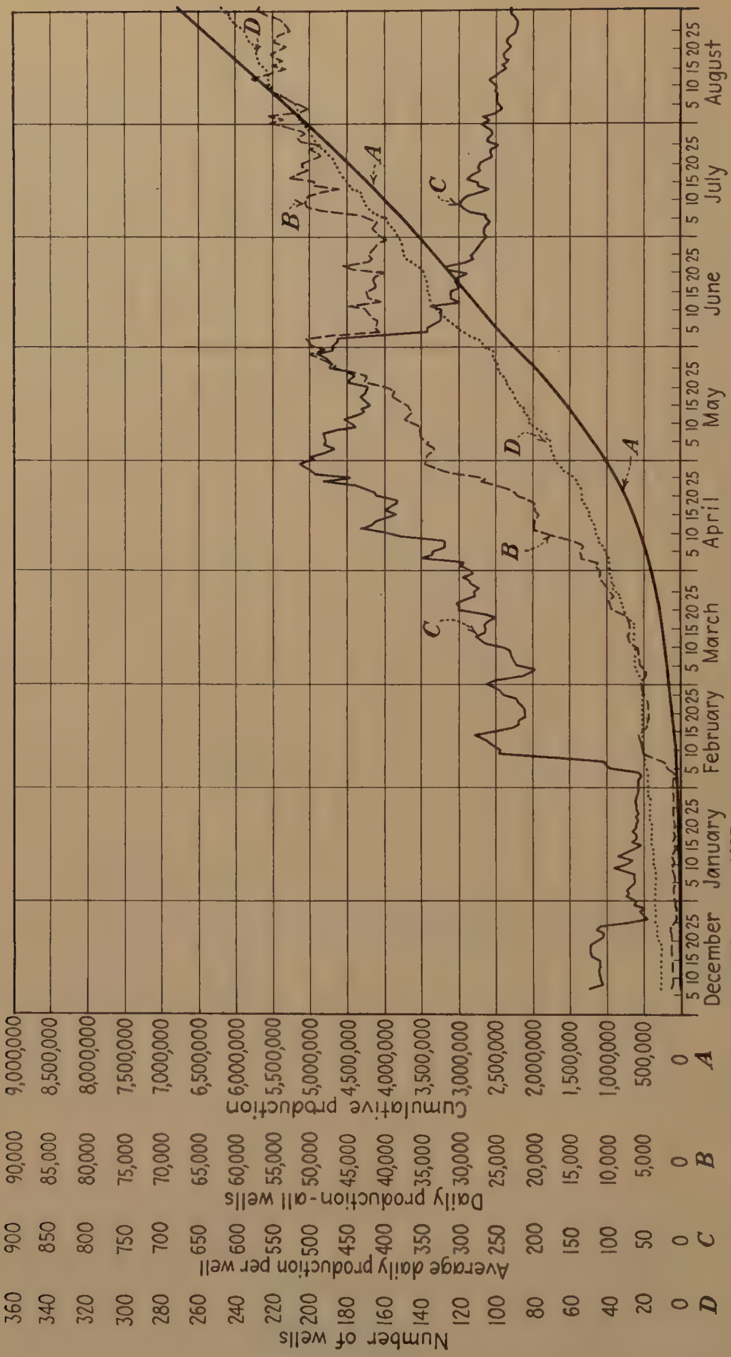

FIG. 6.—NUMBER OF WELLS AND PRODUCTION, WILMINGTON OIL FIELD, SEPT. 15, 1937.

CONCLUSION

To date (Sept. 15, 1937), with one-half of the field partly developed, there are approximately 2100 acres of proven oil land. The rapid development due to competitive drilling reached a potential of 113,455 bbl. per day for the month of August 1937, from 204 wells. Production as of Sept. 1, 1937, is 56,955 bbl. per day from 248 wells, with quite a number of wells heavily curtailed in the highest portion of the field. The field produced 6,804,380 bbl. from Dec. 7, 1936, to Sept. 1, 1937, but it is too early to predict its future production because only the westerly part of the entire potential area has been developed; the portion that lies in the city of Long Beach has not yet been opened for drilling.

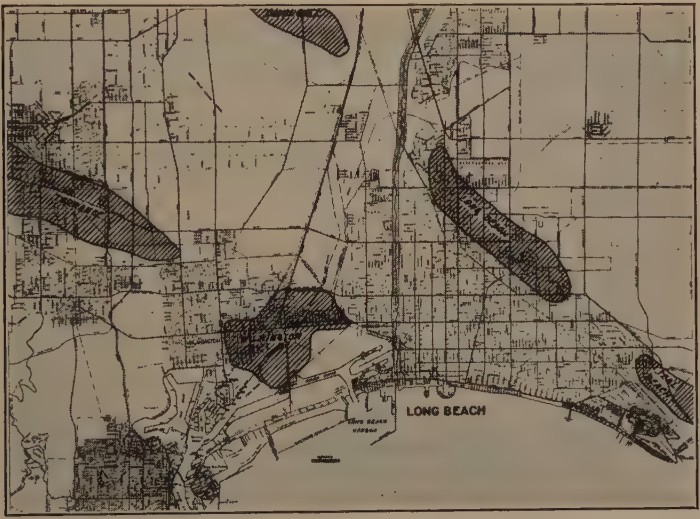

FIG. 7.—LOCATION OF WILMINGTON FIELD IN RELATION TO OTHER OIL FIELDS, CALIFORNIA.

At the present time (Sept. 15), 260 wells have been completed, divided into 68 pumping wells and 192 flowing wells. Drilling wells have decreased until on Sept. 15 there are only 25 active wells. The number of wells and the zones from which they are producing are as follows:

Location of Wells	Number of Wells	Location of Wells	Number of Wells
Tar zone	12	Upper Terminal zone	70
Tar and Ranger zones	13	Upper and Lower Terminal zones	9
Tar, Ranger and Upper Terminal zones	1	Lower Terminal zone	1
Ranger zone	88	Ford zone	2
Ranger and Upper Terminal zones	64		260

With the opening for drilling, in the near future, of land in the city of Long Beach, the field should show a large increase in productive area.

APPENDIX

April 5, 1938

Since the report on the Wilmington field was written on Oct. 1, 1937, numerous new developments have occurred.

The drilling restrictions on properties in the city of Long Beach were lifted on Nov. 11, 1937, and subsequent development proved that another normal fault exists in the Long Beach harbor area, which is now referred to as the Long Beach harbor fault. Production of 150 to 550 bbl. of 16° to 18° A.P.I. gravity crude is found east of the fault from the Ranger zone, whereas to the west of this fault the Ranger zone produces from 500 to 2700 bbl. of 20° to 24° A.P.I. gravity oil. The wells producing Upper and Lower Terminal zones combined, west of the fault, yield production of 5000 to 8200 bbl. of 22° to 28° A.P.I. gravity oil, and east of the fault the entire Terminal zones are barren.

Proven area of the field is now about 3200 acres. Daily production as of March 30, 1938, was 104,710 bbl. from 399 active producing wells, with a large number of wells heavily curtailed voluntarily. Drilling wells number 33 and should continue for several months before the proven area is developed.

DISCUSSION

(*Ernest K. Parks presiding*)

A. Gregersen,* Los Angeles, Calif.—I should like to ask about the uniformity of the top of the Repetto and the base of the Middle Pico?

E. J. Bartosh.—This varies, more or less, not having the exact contacts of any particular well. The most significant part is indicated on the electrical logs. There is a very decided change in character of formation indicated in the resistivity recording, and also the permeability curve, which is the only positive indication we have. The top of Middle Pico is rather indefinite at this time.

In the cores of a well drilled on the north flank, Middle Pico formation was found and a drilled interval of about 500 ft. indicated that a point considerably below the Repetto contact had been reached. The Repetto is not known to be a normal section. We arrived at this deduction by the approximate position of the middle Pico faunal zone.

The unconformity is rather a vague point in some areas. On one electrical log it seems to be very much in evidence. The north-south section brings it out better than the east-west section. I have an upper to middle Pico contact on a logged section and it suggests practically a horizontal bedding plane. The Upper Pliocene and Repetto contact indicated on cross sections suggests no disturbance whatsoever from Repetto time on.

(Since the reply above was written we have found evidence that a thin Middle Pico member is present in the central area of the field and lies unconformably upon the Repetto, with an unknown amount of Repetto section eroded, if any, although cross sections suggest some erosion having taken place. In the Long Beach harbor area the Upper Pliocene rests unconformably upon the Repetto.)

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* Geologist, The Texas Company.

El Segundo Oil Field, California

By L. E. Porter*

(Los Angeles Meeting, October, 1937)

El Segundo field is about 14 miles southwest of the central portion of the city of Los Angeles, immediately adjacent to the town of El Segundo and the Standard Oil Company's El Segundo refinery site. The field is served and bisected by several major highways connecting the beach cities on the west side of the Los Angeles Basin. The exact location of the field and its position with respect to other producing areas is shown on the map covering this portion of the Basin (Fig. 1).

The Republic Petroleum Co. discovered the first commercial production in the area when it completed its El Segundo No. 1 (sec. 18, T. 3 S. R. 14 W.) at a depth of 7402 ft. on Aug. 24, 1935, flowing at the rate of about 400 bbl. per day, 28° gravity oil. The producing horizon in this well consists of about 72 ft. of conglomerate and schist conglomerate situated below the nodular shale (Miocene). The true (or solid) schist (Franciscan) was encountered and penetrated some 20 ft. in the bottom of the hole.

This paper gives a report on the history of development and oil production to date, and also submits the writer's interpretation of structural conditions as determined from such development. The limited development, together with the complex and variable nature of the producing horizon, makes any interpretation of the structure at present only tentative, and any forecast for a given well extremely hazardous.

HISTORY OF OIL AND GAS PRODUCTION

The El Segundo field has produced approximately 1,920,000 bbl. of oil. It has 27 producing wells and 14 drilling wells or locations. The present daily rate of production is about 13,400 bbl. The production history of the field to date is shown in Table 1. The principal companies operating or owning leases in this field are: Caminol Company, Geo. F. Getty, Inc., Ohio Oil Co., Republic Petroleum Co., Pacific Western Oil Corporation, Royalty Service Corporation, Richfield Oil Corporation, Standard Oil Company of California, The Texas Company, Union Oil Company.

Manuscript received at the office of the Institute Oct. 13, 1937.

* Richfield Oil Corporation, Los Angeles, California.

TABLE 1.—*Petroleum Production, El Segundo Field*

Date	Number of Producing Wells	Barrels per Month	Daily Average, Bbl.
1935			
September	1	4,418	148
October	1	4,728	153
November	1	5,247	174
December	1	5,166	167
1936			
January	1	4,986	161
February	1	4,624	165
March	1	4,576	147
April	1	4,456	149
May	2	10,058	324
June	2	11,817	394
July	2	11,742	369
August	3	10,252	331
September	3	12,573	419
October	3	11,815	381
November	3	11,317	377
December	4	65,119	2,100
1937			
January	4	66,025	2,130
February	6	55,730	1,990
March	15	122,751	3,960
April	16	166,372	5,548
May	18	172,635	5,369
June	21	179,038	5,968
July	24	272,304	8,784
August	25	348,653	11,247

The development to date has been confined principally to secs. 7 and 18, T. 3 S, R. 14 W. More recent development indicates that the town-lot area north of the refinery site in sec. 12, T. 3 S, R. 15 W, will be opened up for considerable development. It is to be hoped that communitized leases will be used in the town-lot area in order to keep the production output on a conservative basis and to maintain the utilization of existing reservoir pressures to their maximum efficiency.

It has been mentioned that the first development was started by the Republic Petroleum Co. in August 1935. This was followed by the drilling of a second well and then a period of comparative inactivity existed until December 1936, when the Richfield Oil Co. brought in its first well on its El Segundo property in the northeast quarter of sec. 18, from a depth of 7435 ft., for an initial production of 2533 bbl. of 27.2° gravity oil. This development started considerable activity in sec. 18, which was followed by successful completions on the Republic, Caminol and Richfield properties. Production up to that time had been confined mainly to the conglomerate and schist conglomerate overlying the true basement schist.

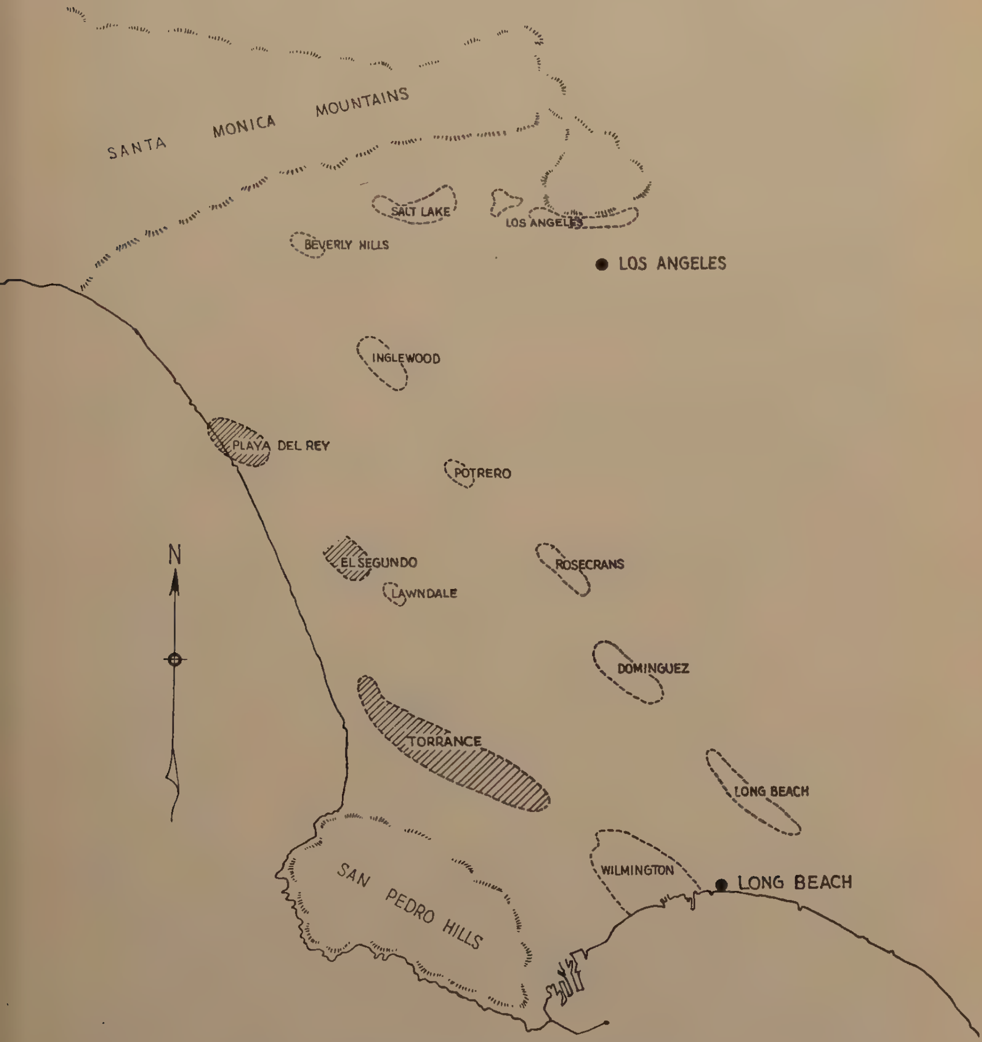

Fig. 1.—Western part of Los Angeles Basin.
Shaded areas are those in which schists occur.

The third stage of development in the field was started when The Texas Company completed its Security No. 1 in the west half of the northwest quarter of sec. 18. This well was completed on May 23, 1937, at a depth of 7253 ft., for an initial production of 4563 bbl. of 26.5° gravity oil. The third stage of development has been confined largely to the area around the section corner common to secs. 7, 12, 13 and 18, or at the intersection of Sepulveda and El Segundo Boulevards. Practically all of the production in this westerly area is being obtained from the fractured schist itself, the conglomerate being decidedly absent.

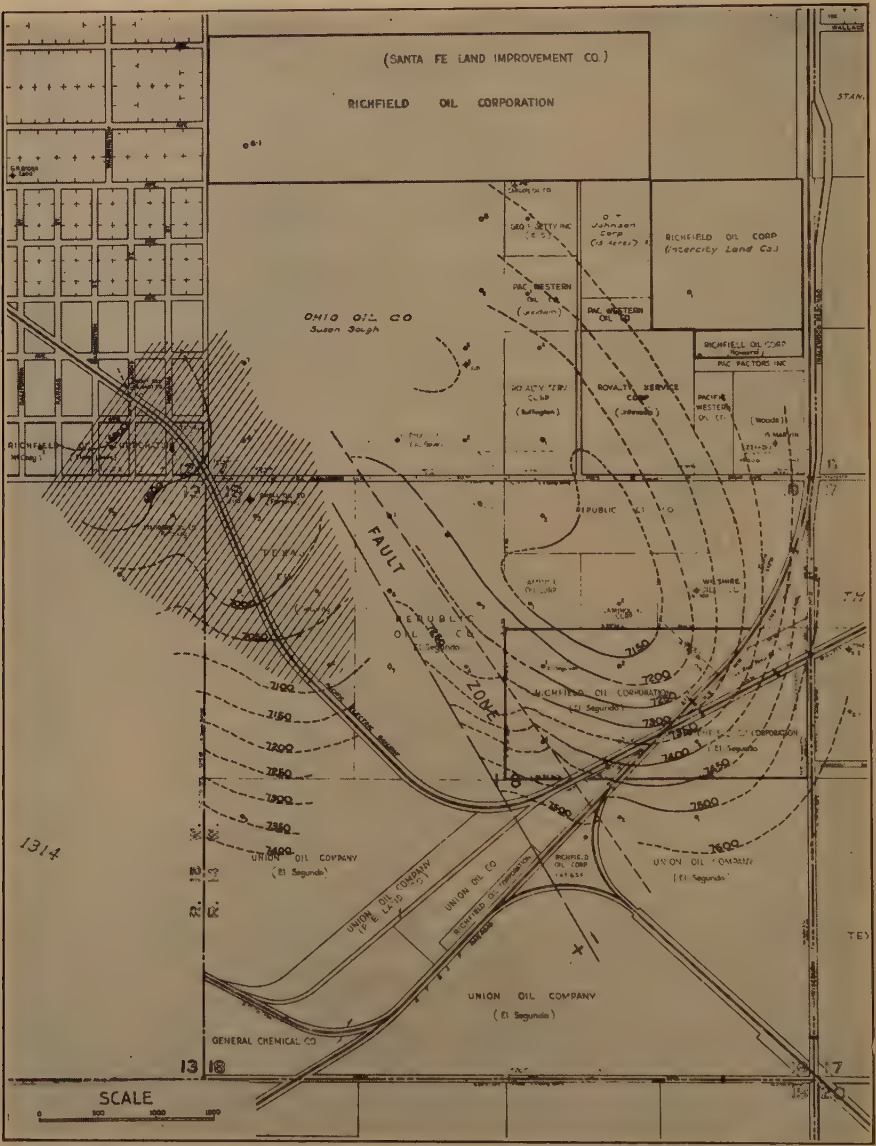

FIG. 2.—SUBSURFACE CONTOUR MAP OF TOP OF PRODUCING HORIZON, EL SEGUNDO FIELD.

Top of conglomerate if present, otherwise top of schist. Datum sea level. Shaded area has little or no conglomerate.

Structure and Stratigraphy

The structure so far is interpreted as that of a faulted schist high, representative of an old structural high that is Franciscan or pre-Franciscan in age. There is some reflection of structural doming in the Miocene sediments, below which production is found. To date, no production has been found above the nodular shale, which immediately overlies the schist or conglomerate.

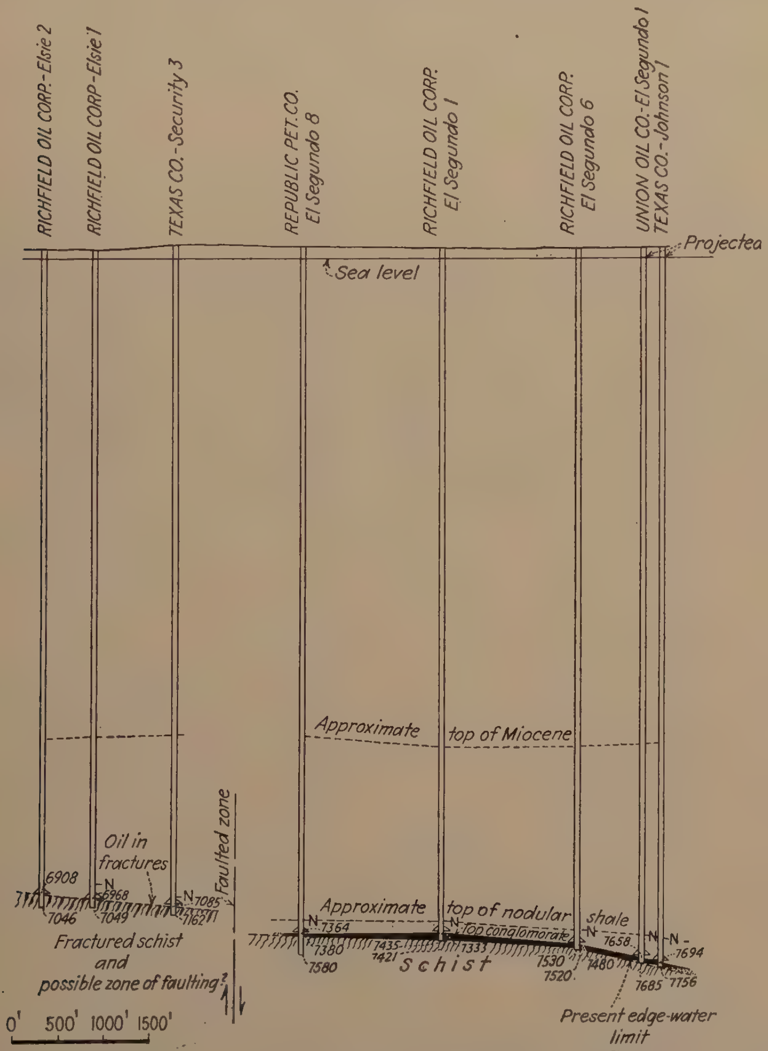
RICHFIELD OIL CORP.-Elsie 2
RICHFIELD OIL CORP.-Elsie 1
TEXAS CO.-Security 3
REPUBLIC PET. CO. El Segundo 8
RICHFIELD OIL CORP. El Segundo 1
RICHFIELD OIL CORP. El Segundo 6
UNION OIL CO.-El Segundo 1
TEXAS CO.-Johnson 1
Projected
Sea level
Approximate top of Miocene
Oil in fractures
Faulted zone
6908
N
6968
N
7085
7046
7049
7162
Fractured schist and possible zone of faulting?
Approximate top of nodular shale
Top conglomorate
N
7364
N
N
7658
N
N
7694
7380
7580
7435
7421
7333
Schist
7530
7520
7480
7685
7756
Present edge-water limit
0' 500' 1000' 1500'

Fig. 3.—Northwest-southeast subsurface section, El Segundo field.

The field has been segregated into two major producing areas separated from each other by a major line or zone of fracturing with the westerly portion of the field on the upthrown side. These two structural divisions are more clearly shown on the subsurface contour map (Fig. 2), in which the contours have been placed on the top of the producing conglomerate, if present; otherwise, on the top of the schist. The exact nature or position of the supposed fault has not yet been wholly disclosed. Future development may find it to be merely a steep escarpment on the schist itself, yet present development strongly suggests that a major break will ultimately be found, the throw of which is indicated to be about 200 feet.

The stratigraphic column or geologic section in the area consists of formations belonging to the Pliocene and Miocene, which overlie the Franciscan schist. The Pliocene-Miocene contact in the central portion of the field is encountered between 5200 and 5400 ft. (The relationship of this contact is in Fig. 3.) The exact top of the Miocene has not been determined through coring, the information being obtained from electrical logs, which have given fair evidence as to the position of this contact. The sediments from about 5200 ft. to the top of the schist, which is encountered from 7200 to 7450 ft., consist mainly of the typical Miocene sands and shales found elsewhere in the Los Angeles Basin. The most interesting unit of this series is the dark brown nodular shale that directly overlies the producing oil horizon. Samples of this shale have been photographed and are shown in Fig. 4. The nodules themselves are gray to brownish gray in color and vary as a rule from ½ to 2 in. in diameter. They appear to be highly phosphatic and occur with a brownish to dark colored banded shale. The dip in the nodular shale so far appears to be nonconformable to the dip of the conglomerate or sand phases of the producing zone.

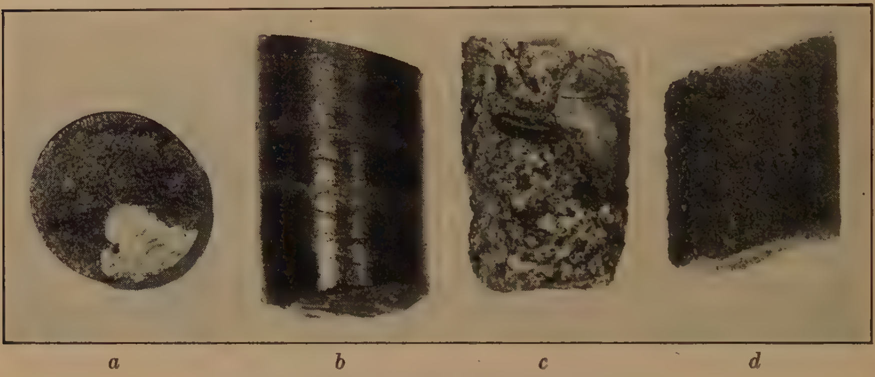

Fig. 4.—Core samples, El Segundo field.
a. Cross section of core showing nodule in nodular shale.
b. Longitudinal section of core showing banded nodular shale.
c. Conglomerate schist contact in core taken from Richfield's El Segundo property.
d. Medium to fine-grained micaceous sand from east side of El Segundo field.

In many ways, the nodular shale, the conglomerate, and the occurrence of the oil in the schist form a condition similar to that found in the lower zones in the near-by Venice and Playa del Rey fields and certain portions of the Torrance field. The El Segundo field differs mainly from Venice in that so far no production has been discovered above the nodular shale, and that in the vicinity of the intersection of El Segundo and Sepulveda Boulevards the wells have encountered schist that has been somewhat fissured through erosion and fracturing. The oil in this field is 27° to 28° gravity whereas the Venice oil varies from 20° to 24°.

In the eastern half of the El Segundo field most of the oil occurs in a conglomerate or schist conglomerate, which apparently has been deposited upon an uneven erosion surface of the schist and its thickness varies from a few feet to as much as 90 ft., the greatest thickness so far having been encountered in the Richfield Oil Corporation's El Segundo No. 1. The color of this formation is generally gray to greenish gray, including irregular pebbles of schist as well as some well rounded quartz and basaltic gravels, some having a diameter as great as 1½ to 2 in. Tests upon the conglomerate indicate a porosity as high as 13 per cent, as shown in core sample *c* in Fig. 4. In the more or less distinct sand encountered in Richfield Oil Corporation's El Segundo No. 6, a porosity as high as 28 per cent has been measured.

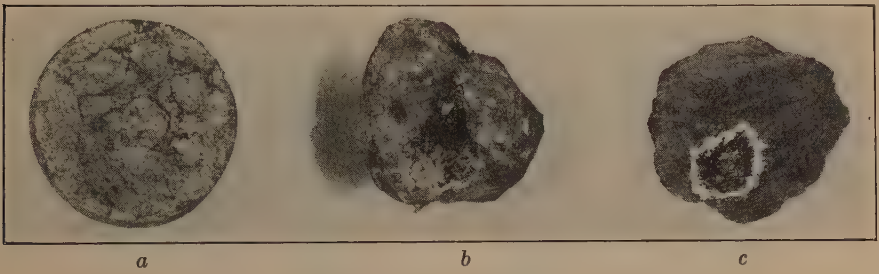

FIG. 5.—CORE SAMPLES, EL SEGUNDO FIELD.

a. Cross section of sample *a* in Fig. 6. Oil in fractures and fissures.

b. Highly fissured and fractured massive schist with large pyrite crystals on inside walls of fissure. Dark spot in center represents hole with 0.35-in. diameter, which runs through entire core. Apparent recementing of fissure is due to pyritization. Sample taken from same well as core in Fig. 6*a*.

c. Highly contorted schist, very dense with pyritic crystal growth approximately 0.3 in. in diameter, growth adjacent to small pinlike holes concentrated in area of about 0.1 inch.

In the so-called western area, or western half of the field, the production so far has been confined to a fractured and irregular schist formation. Core samples that show large pyrite crystals on the inside walls of fissures have been extracted from some of the wells. Examples of these are shown in Fig. 5. In one example shown there, a hole as large as 0.35 in. has been measured. There is much speculation as to the occurrence of production in this so-called schist horizon. Tests have been made on certain samples for their porosity; for example, in sample *a* of Fig. 6, from Richfield Oil

Corporation's Elsie No. 2, a porosity of 14.5 per cent was found. This sample also shows the oil contained in the crevices of the core. It has all the appearance of having been altered, either by weathering or hydrothermal action, or both. The solid schist found at the bottom of the hole has a porosity of only 5.8 per cent (sample *b*, Fig. 6). These low porosities strongly suggest that the occurrence of oil in this western area must be confined principally to the fissures and fractures that have been made in the schist subsequent to its alteration.

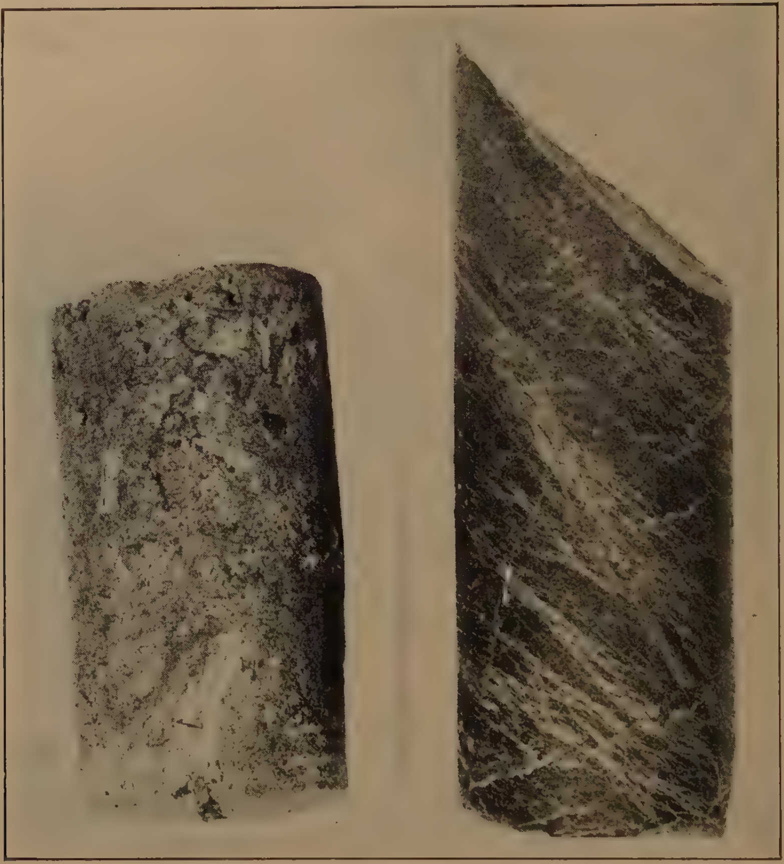

FIG. 6.—CORE SAMPLES, EL SEGUNDO FIELD.
a. Fractured and fissured schist from Richfield's Elsie lease.
b. Solid green talco schist from same well as core *a* but in lower portion of hole.

RELATIONSHIP OF OIL AND GAS ACCUMULATION TO THE STRUCTURE

Following the contours on Fig. 2, it will be found that the 7500-ft. contour in the eastern area probably makes the edge-water line in this portion of the field. Edge water has been definitely encountered in the Richfield Oil Corporation's Santa Fe No. 1, the Union Oil Company's El

Segundo No. 1 and No. 2 in sec. 18, and The Texas Company's Johnson wells No. 2-1 and No. 2-2 in sec. 17. Just where the trace of this contour will progress north and westward cannot as yet be determined. The wells in this eastern area have been wells of low initial gas-oil ratios varying from 500 to 800 cu. ft. of gas per barrel of oil produced. The largest well in this area has been the Richfield Oil Corporation's El Segundo No. 1, which has produced approximately 300,000 bbl. since it was completed in December 1936. Subsequent wells, however, have not been so fortunate, and have shown the direct influence of counter drainage. In the western area, the discovery of which is credited to The Texas Company in its Security No. 1, production has been very erratic. The initial well, Security No. 1, has produced in excess of 400,000 bbl. in about five months, while other wells alongside it are capable of only 100 to 200 bbl. per day.

Development in the field to date has suggested that approximately 850 acres are more or less proved. The general spacing program has been patterned on about one well to each 10 acres. It is quite possible that the field will extend west and northwesterly, so that ultimately it may include as much as 1500 to 1600 acres. The latter figure can be considered as only tentative. The writer wishes to emphasize again that the evidence disclosed to date is so conflicting that it is impossible to predict with any certainty the productivity of any property or well. Each must be considered as a semiwildcat. There are examples of wells producing several thousand barrels a day being offset by wells producing less than 100 bbl. a day. The reasons for this difference are as yet unknown.

There is much speculation as to the probable recovery of crude oil per acre from this field. Because of the irregularities mentioned, this cannot be determined for any practical use. Taking one area, for example, in the eastern portion, it is estimated that for an average zone of 50 ft. of conglomerate, and one well to 10 acres, the ultimate recovery will be about 22,000 barrels per acre, or approximately 440 bbl. per acre-foot for the net footage involved. Immediately adjacent to this area, several wells have been drilled from which the production is not sufficient to return the lifting costs. Of the approximately 1,920,000 bbl. of oil produced in the field to date, over 1,100,000 bbl. are attributed to four outstanding wells. This cumulative yield from the four wells represents about 58 per cent of the total production to date. In the western area, with fractures and fissures in the schist which have had a measured width as high as 0.35 in. and the solid portions have shown a porosity less than 10 per cent, the wells offer considerable speculation as to their ultimate recovery per acre.

Gravity and Character of Oil

The average gravity of oil in this field varies from 27° to 28°. The analysis indicates about 1.5 per cent sulphur, and a gasoline content of 28.6 per cent at 437° F. The crude also yields about 4.5 per cent of gas-oil with a gravity of 31° and a sulphur content of about 1.08 per cent at the end point of 685°. Some samples have tested 58.6 per cent in fuel oil, the gravity of which is 16.5°.

Drilling and Production Methods

The rotary method of drilling has been used exclusively throughout the field. The wells are drilled to a depth of 7200 to 7400 ft. in approximately 50 to 60 days at a cost of about $70,000 to $80,000 per well, depending upon the type of casing program. One casing program is 13⅜ in. at about 1100 ft., 8⅝ in. on top of the oil zone and 6⅝-in. liner in the zone. Another casing program is 11¾ in. at 700 ft., 7 in. on top of the oil zone around 7200 ft. and a 4½ or 5-in. perforated liner.

Summary

1. The production in the eastern area of the field is confined to the conglomerate and schist conglomerate. Flowing wells to date have shown some tendency for counter drainage. Porosity test of conglomerate and sand samples indicates a porosity as high as 28 per cent. The recovery per acre will probably be low but will be found to be strictly dependent upon the thickness of the producing zone for any given well.

2. In the western area the production seems to be confined mainly to fractured and fissured schist, in which the voids no doubt have been promoted through action of hydrothermal waters, faulting and fracturing. Tests on the solid schist samples indicate a porosity of 5 per cent or less, which eliminates such formation samples as a possible reservoir, confining the accumulation to the subsequently created voids and fissures. The high pressure and sustained production in the initial wells suggests that such fissures and faults either exist to considerable depth in order to promote an adequate reservoir or that such fissures are being fed by an adjacent sedimentary reservoir as yet unrecognized. So far it is impossible to predict the recovery per acre in this type of material.

The character of the reservoir and the type of material seen in cores to date would suggest that proper well spacing and well control should be used to maintain adequate reservoir pressures and obtain the greatest recovery of oil.

Acknowledgments

The writer is indebted to the members of various operating companies in the field for their courtesy in discussing field problems and affording information that otherwise would not have been available. He is particularly indebted to Messrs. H. W. Hoots, K. L. VonderAhe, W. K. Kreiger and T. H. Acres, of the Richfield Oil Corporation, for much of the information contained herein.

Ten Section Field, Kern County, California

By H. T. Wyatt* and A. S. Baptie†

(Los Angeles Meeting, October, 1937)

The Ten Section field is approximately 10 miles southwest of Bakersfield, Kern County, Calif. (Fig. 1). There is no surface evidence of the existence of the Ten Section structure, which subsurface exploration has shown to be a gently folded, anticlinal dome. Regionally, this field occurs as a fold in the deeper beds of the gently rolling floor of the San Joaquin Valley. It is on the easterly slope of the valley, its position with relation to the axis of this syncline not having been determined.

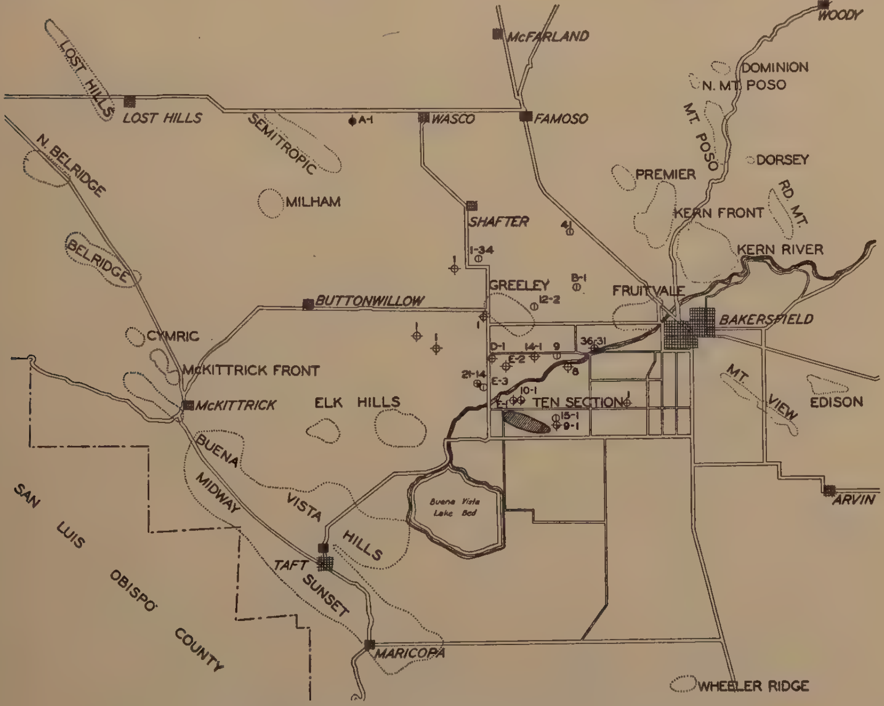

Fig. 1.—Southern part of San Joaquin Valley oil fields.

The field was discovered by Shell Oil Co. with the completion of well Stevens A-1, on June 2, 1936, at a depth of 7888 ft. The location for this

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well was chosen as a result of geophysical prospecting. As a result of the discovery, a second well was drilled, which penetrated 1188 ft. of the so-called Stevens zone. This second well, KCL A-6-29, was drilled to a total depth of 8984 ft. and found oil and gas in the upper 614 ft. of the Stevens zone. Since the completion of this well, five additional wells have been drilled and development is proceeding steadily. The present potential of these seven wells is about 15,000 bbl. of oil per day, which is curtailed to about 3000 bbl. daily.

Soon after discovery three outpost wells were drilled at locations approximately 1¼ miles to the north and 2 miles to the east of the discovery well. All were unproductive after having penetrated from 525 to 740 ft. of the Stevens zone.

Stratigraphy and Lithology

The idealized column shown on Fig. 5 is illustrative of the present general, though tentative, conception of the field's stratigraphy. Immediately beneath the surface alluvium there are approximately 900 ft. of loosely consolidated, fresh-water sands and gravels interspersed with occasional thin layers of clays and sandy silts. These beds probably represent either the Tulare formation or the Kern River series of the upper Pliocene. Below these there occurs approximately 6000 ft. of Pliocene deposits, which have not been classified. These beds may be equivalent to the Etchegoin formation. This portion of the section occurs as a monotonous series of alternating claystones, siltstones and sands, which apparently are of fresh-water, brackish and marine origin.

The uppermost portion of the Miocene is represented by the so-called brown shale, which is approximately 915 ft. thick. The Stevens zone, from which production is obtained in this field, is also of upper Miocene age and lies directly beneath the brown shale. This zone has not been definitely correlated with any of the established Miocene formations in this area.

The layers that form approximately the top 6900 ft. of the section in this area are almost entirely composed of an alternating series of soft to firm claystones, siltstones, and loose to slightly consolidated, poorly cemented, easily friable sands. The uppermost beds of the Miocene (the brown shale) are composed of a series of uniformly deposited, dense, well indurated, generally well laminated, platy, dark brown shales. This member is characterized by numerous to abundant micro-organisms, pyritized diatoms, and resinous fish remains with occasional thinly bedded, dark brown chert streaks.

The Stevens zone is made up of a series of sand beds separated by shale streaks. As is apparent from the idealized transverse section (Fig. 3), there is a noticeable irregularity in the thickness of the various sand and shale members comprising the Stevens zone. This lack of uniform thickness is believed to be due to irregularity in depositional conditions. This belief is substantiated by common cross-bedding and irregular bedding in the sand members themselves, and in the shales.

In general, the sands of the Stevens zone are moderately to fairly well cemented, compact, poorly to well sorted, medium-grained to slightly coarse in texture, and generally free from fine silt. The average porosity of the sands in the productive horizons is 16 per cent, the range varying from 12 to 20 per cent. Not enough data have been obtained to furnish a reliable index as to the permeability of these beds.

Structure and Accumulation

The structure illustrated on Fig. 2 is that of a gently folded, elongated anticlinal dome. An idealized transverse section crossing the field approximately through the anticlinal culmination is presented on Fig. 3, which illustrates the steeper dip of the southwest flank as compared to the northeast. It should be realized that the structural picture offered in the accompanying plates is unavoidably distorted because it was necessary to use different scales for the horizontal and vertical distances. Along its longitudinal axis the structure has a gentler dip than on either flank. An idealized longitudinal section shown on Fig. 4 illustrates this profile. On this drawing a structural break southeast of the crest is postulated. The nature and exact position of this break is undetermined, only one well (A-58-29) having been drilled on the southeast side of the break.

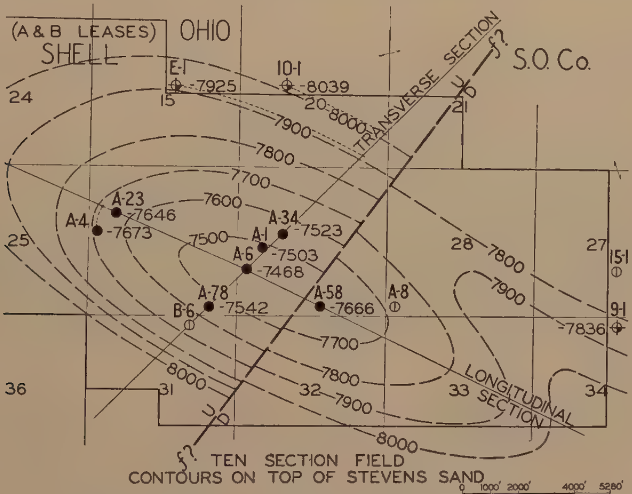


Fig. 2.—Contours on top of Stevens sand, Ten Section field.

As indicated by the generalized contours shown on Fig. 2, the maximum closure in the southeast block has been assumed to be approximately

200 ft. Sufficient drilling has not yet been done to determine the maximum closure in the northwest block, but it is believed to be more than 500 feet.

The oil and gas accumulations in the Stevens zone, in the upper 614 ft., at the crest of the structure, apparently are controlled entirely by the overlying impervious shale beds and the underlying bottom and edge water. Five separate sand intervals have been found to be oil-bearing. These sands and their approximate thicknesses are shown on Fig. 5*b* in conjunction with the generalized lithologic and electrical logs.

Sand I was first penetrated 56 ft. in the discovery well. At this point the well produced at a maximum rate of 858 bbl. of oil daily, gravity 60.4° A.P.I. and 13,656 M cu. ft. of gas per day. Recent coring and production tests have indicated that while the gas-oil contact is approximately horizontal, it is probably lower in sand I than is shown on Figs. 3 and 4. Below the gas-oil contact in this and lower zones there exists a dark oil having an average gravity of approximately 35° A.P.I. The extent of the oil accumulation in sand I has not been determined and the limits shown on the accompanying drawings are arbitrary.

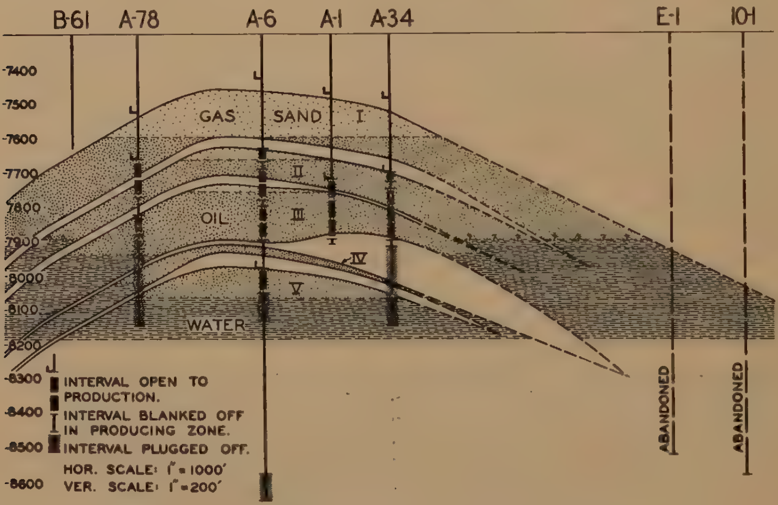


Fig. 3.—Transverse section, Ten Section field.

In sand II, the oil-gas contact is nearly horizontal, and at the crest of the structure the contact occurs at about the mid-point of the sand body.

Sand III, at the crest of the structure, is the thickest single sand body that occurs in the productive series. The gas cap in this sand is comparatively small. Some of the more pronounced variations in irregular deposition in the Stevens zone are apparent in sands III and IV.

Sand IV has never been separately tested. It was excluded from production in KCL A-6-29. In KCL A-34-29 it was tested simultaneously with the upper portion of sand V, which was demonstrated to be water-bearing. Although the water-location test that disclosed the latter information did not evidence any water in sand IV, it cannot be said conclusively that the sand is not water-bearing at that location. However, inspection of the cores and the electrical log revealed that sand IV in KCL A-78-30 was undoubtedly water-bearing. Thus such oil or gas as may exist in this sand will be confined to a limited area on the crest of the structure.

Approximately 80 ft. of sand V was found to be oil-bearing, and after lower water-bearing sands were plugged 70 ft. of this zone was tested in KCL A-6-29. This interval produced 1535 bbl. clean oil daily, gravity 34.3° A.P.I., and 1541 M cu. ft. gas. From this evidence, and from the data obtained from KCL A-34-29 and A-78-30, it is apparent that the oil accumulation in sand V has a very limited extent.

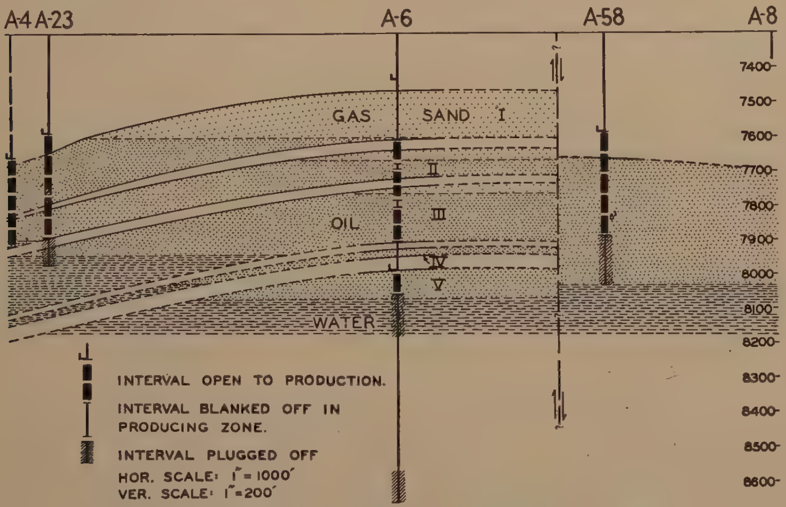


FIG. 4.—LONGITUDINAL SECTION, TEN SECTION FIELD.

CORRELATION METHODS

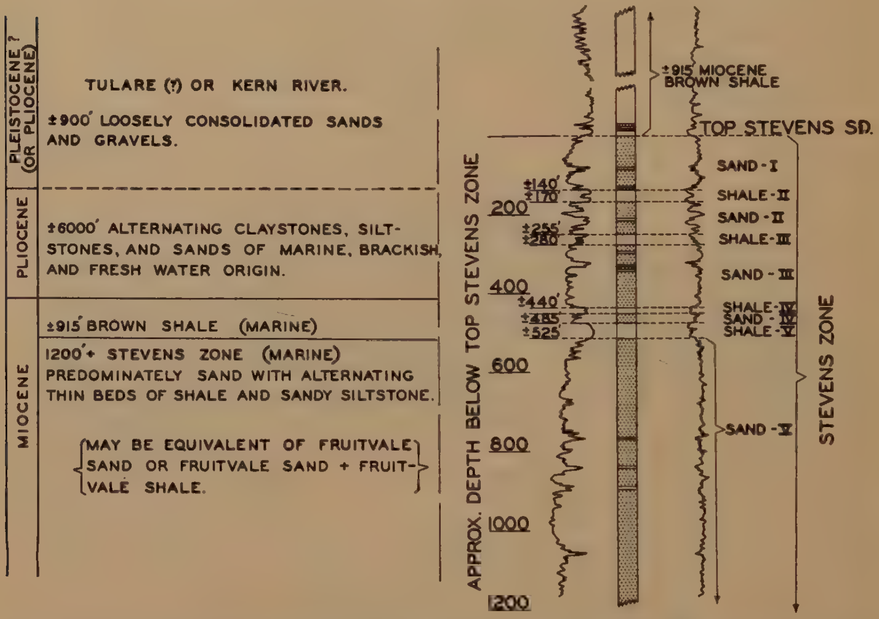
Two principal methods have been used in this field for making subsurface correlations: (1) lithologic, (2) electrical logging.

Lithologic correlations in the Stevens zone are made from cored sections. Correlations by this method have proved to be reliable and are, in general, readily made. Lithologic correlation above the top of the Stevens zone has not been necessary for development purposes.

The lithologic correlations all have been augmented and substantiated by correlation of electrical logs. It is the practice to record a complete log below the shoe of the surface water string. These logs are sufficiently uniform in general characteristics from well to well to show convincing and apparently reliable correlations throughout the entire section.

Development Procedure

The practice has been to locate wells in such a manner as to determine as early as possible both the vertical and horizontal limits of the oil and gas accumulation, and to determine the general outline of the subsurface structure. This is being attained by locating wells along two lines that approximate the longitudinal and transverse axes. An early generalized conception of the subsurface structure has been formed, which will be augmented as to detail by the drilling of additional transverse sections. The detailed delineation of the subsurface structure and accumulations both down flank and along the plunges is considered necessary in view of experience in other fields, which has shown that the accumulation down plunge is sometimes more extensive than the limits of accumulation along the generally steeper flanks opposite the crest would indicate.


PLEISTOCENE ?
(OR PLIOCENE)
TULARE (?) OR KERN RIVER.
±900′ LOOSELY CONSOLIDATED SANDS AND GRAVELS.
PLIOCENE
±6000′ ALTERNATING CLAYSTONES, SILTSTONES, AND SANDS OF MARINE, BRACKISH, AND FRESH WATER ORIGIN.
MIOCENE
±915′ BROWN SHALE (MARINE)
1200′+ STEVENS ZONE (MARINE)
PREDOMINATELY SAND WITH ALTERNATING THIN BEDS OF SHALE AND SANDY SILTSTONE.
MAY BE EQUIVALENT OF FRUITVALE SAND OR FRUITVALE SAND + FRUITVALE SHALE.
APPROX. DEPTH BELOW TOP STEVENS ZONE
200
400
600
800
1000
1200
±140′
±170′
±255′
±280′
±440′
±485′
±525′
±915 MIOCENE BROWN SHALE
TOP STEVENS SD.
SAND - I
SHALE - II
SAND - II
SHALE - III
SAND - III
SHALE - IV
SAND - IV
SHALE - V
SAND - V
STEVENS ZONE

a *b*

Fig. 5.—(*a*) Generalized stratigraphic column; (*b*) generalized electrical log and lithologic column, Stevens sand zone.

When drilling the first wells, the practice was to core through the oil-bearing formations into the underlying water-flooded sands to determine the vertical limit of the oil accumulation. In these early wells the determination of the fluid content of the sands was made by drill stem and/or production tests. As experience was gained, it became possible to judge the fluid content of the sands solely by inspection of the cores. Thus, the present practice of determining the vertical limits of accumulation is confined to core inspection alone; drill-stem or production tests are made only in exceptional cases.

All wells have been drilled with steam-operated, conventional rotary drilling equipment and the customary 136-ft. steel derricks. Drag bits are used for drilling all formations except the brown shale, which requires the use of rock bits. Coring is generally undertaken with wire-line core barrels. Wells are now drilled in less than two months, whereas six months was required for the drilling of the discovery well.

The derricks and all surface equipment except the well-head connections are removed upon completion of the wells, for use in later drilling.

Two standard casing programs are employed; the first provides an extra string cemented so as to exclude the gas-bearing horizons from production; the second, which is employed in the structurally lower locations where gas-cap conditions are not encountered, merely provides for cementing a single water string above the main oil horizon. With the second program it is the practice to set 40 ft. of 16-in. stovepipe casing as a conductor and cement approximately 1000 ft. of either 11¾ or 10¾-in. slip-joint casing to shut off surface waters. At the top of the oil zone the hole is reduced to 7⅝ in. and is carried to the final depth of the well before the 7-in. water string is cemented. The latter is cemented above the oil zone with sufficient cement to fill behind the casing for 1000 ft. or more. A 4¾-in. perforated aluminum liner is hung opposite the horizon to be produced. Aluminum liners are employed because of the rate of edge-water encroachment in the several sands, and it is desired to complete the early wells so that later intermediate cementations can be made as easily as possible.

PRODUCTION PROCEDURE

Figs. 3 and 4 show the position of the oil and gas accumulations as determined, or assumed, to date; that is, the oil-gas contact at a depth of approximately 7650 ft. below sea level and the oil-water contact approximately 7950 ft. below sea level in the several productive horizons. Apparently oil and gas accumulated in this field without regard for natural barriers between the several productive sands. Development has shown, however, that there is no interconnection between the various sand members within the limits of the field. Therefore, while the conditions at the time of accumulation resulted in the oil-water and oil-gas contacts being at approximately the same level in all the sands, it can be expected that the effect of depletion by production will be variable. Consequently, the oil and gas accumulations in the separate sands must be treated individually for the purpose of exploitation.

Gas-oil ratios typical of gas-cap conditions have been experienced in several zones tested on the crest of the structure above the level of the oil-gas contact. Beneath the gas cap, oil is produced with a gas-oil ratio of approximately 700 cu. ft. per barrel initially. This is believed to represent the normally saturated condition of the oil.

It has been observed, from the brief history available, that the wells in the vicinity of the gas cap have a tendency to produce at increasingly greater gas-oil ratios. These increases are minimized by producing the structurally lower wells at a relatively higher rate than the up-structure wells.

Original bottom-hole pressures in this field are of the order of 3500 lb. per sq. in. Although a total production of approximately 815,000 bbl. of oil and 4,750,000 M cu. ft. of gas have been produced, it has not been possible to observe any reduction in formation pressure.

The aim of the present development and production policy, in addition to determining the subsurface structure and limits of accumulation, is to avoid dissipation of gas and gas energy and to control the movement of the gas-oil and oil-water contacts. To do this may require the separate (or carefully segregated) exploitation of the several producing sands; also, the location of the wells in "rings" around the structure, at the optimum position between the oil-water and gas-oil contacts.

Chapter III. Engineering Research

The Origin of Petroleum

By E. Berl*

(Oklahoma City Meeting, October, 1937)

This may be a most unnecessary paper—from what does crude oil come and how was it formed? Many people, inside and outside of the petroleum industry, believe that we have actually enough oil, and that we can easily produce very important products from this extremely valuable raw material. The writer believes, however, that the answer to this question concerning the parent material and the formation of oil is of broader interest, because it may be that from the answer to these problems it would be possible to get answers to other important industrial questions. Therefore, a study in this line seems to be justified, and the writer will submit some of the results which he has collected during more than ten years with many very capable collaborators, to whom his thanks may be expressed on this occasion.

Older Theories

There is no doubt that plants were the parent material of coals, but opinion is divided as to the parent material of crude oil and asphalts. One group of specialists believed that they were formed from dead fish. The hydrocarbons of crude oil were formed by the splitting off of CO_2 from fatty acids formed by the saponification of the fat (glycerides) of fish. Enormous quantities of crude oil are present in many places on the earth, very often in several nonconnected horizons at the same location. This could hardly be explained by the so-called "catastrophe theory," which states that fish died through the entrance of salt water into fresh water, and vice versa. Furthermore, this theory cannot explain the presence of aromatic hydrocarbons, which can be found in nearly all oils, especially in the oil of the Netherlands Indies, which has more than 50 per cent of aromatics. Geological and chemical observations both lead to the belief that the temperature of formation of asphalt, crude oils and coals, perhaps with a few exceptions, did not exceed 200° C. Chlorophyll and haemin derivatives, which decompose above 200° C., have been found in all these materials by Treibs and others. Thermodynamic considerations show that the temperature necessary for the conversion

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of aliphatic hydrocarbons into aromatic hydrocarbons is certainly higher than 200° C. It is known that in industrial processes, which have to be carried out in rather short periods of time, conversion temperatures in the neighborhood of 600° to 800° C. are necessary to convert aliphatic hydrocarbons partly into aromatic hydrocarbons.

Mendelejeff's theory that oil hydrocarbons were formed from endothermic metal carbides and water has not found broad support. Many oils are optically active. They must, therefore, result from optically active material. The inorganic source mentioned above for crude oil could produce only optically inactive material.

Concerning asphalt, there is the leading, or probably misleading, theory that all asphalts are formed by the oxidation of hydrocarbons. Asphalt can be found in practically all crude oils. It may be remembered that this country produces more than five million tons of asphalt per annum from the distillation of crude oil against 100,000 tons per annum of natural asphalt from Trinidad. It is known that natural asphalt has been discovered at depths of about 7000 to 8000 ft. It is hard to believe that under those conditions free oxygen could be present to oxidize and convert oxygen-free aliphatic hydrocarbons into phenolic compounds present in asphalts. The fact that asphalts are often found at the outcrops of oil fields finds its explanation in that higher temperature and pressure in the interior of the field accelerate the conversion of oxygen and sulphur-containing asphalts into oxygen and sulphur-free hydrocarbons.

New Theory

In the following deductions we will prove that these older theories cannot be right. We will show that cellulose and other carbohydrates and similar products, like algin acids and pectic acids present in organic plant material such as seaweed and algae, can be transformed in the laboratory into asphaltlike materials under the conditions that may have prevailed during their formation in nature. We can prove that asphalts are the parent material of crude oil and that, through their transformation, aliphatic hydrocarbons as well as aromatic and hydroaromatic hydrocarbons can be formed. We will show that a very simple way to form aromatic and naphthenic substances from aliphatic substances is the conversion of carbohydrates by chemical influence and moderate heat.

There is no other material formed by nature in such enormous quantities as carbohydrates. Lippmann[1] gives the estimates shown in Table 1. There is no doubt that in former geological periods the carbon dioxide content of the atmosphere was much higher and that the growth of plants in view of the higher temperature all over the earth, even at the poles, was more intensive than it is today. If all the plants now growing on the earth could be converted quantitatively into oil, only 2⅓ years would be necessary to produce the actual known oil reserves.

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[1] *Ind. Chem. Eng.* (1935) **105**.

TABLE 1.—*Estimates of Carbohydrates (Lippmann)*

Carbohydrates	Metric Tons of Carbon Content
CO_2 content in atmosphere	6×10^{11}
C content in plants	2.7×10^{11}
Annual production of cellulose and other carbohydrates	0.03×10^{11}
Anthracites	4.2×10^{11}
Bituminous coals on the earth	40×10^{11}
Bituminous coals in the U. S. A.	25×10^{11}
Lignites	15×10^{11}
Peat	11×10^{11}
Crude oil	0.07×10^{11}

DECOMPOSITION OF CARBOHYDRATES

Heat Instability of Carbohydrates and Lignin.—It is known that carbohydrates of all kinds are very reactive substances. Dextrose, for instance, can be decomposed in more than 20 different ways. The carbohydrate content of plant debris that is covered by inorganic material, especially carbonates of calcium and magnesium, zeolites, and other silicates, can be decomposed by heat-treatment with the formation of water-soluble substances, which afterward undergo further geochemical changes and form crude oil. On the other hand, they may be converted into materials rich in carbon and rather poor in oxygen in such a manner that water-insoluble carbohydrates, like cellulose, pass only partly through a water-soluble stage. In such a way bituminous coals are formed.

Using the so-called feather manometer test, we investigated the influence of rather high temperatures on different carbohydrates like sugars, cellulose and cellulose humic acids, and on lignin and lignin humic acids. Cellulose (we investigated ramie) shows a much higher stability than the lower carbohydrates. Experiments carried out in the absence of oxygen and in the presence of oxygen showed that with the latter the speed of reaction is increased more than 30 times.

Cellulose humic acids show a remarkably higher heat stability than all carbohydrates, cellulose included. Lignin is more stable than cellulose humic acid. Both are less stable than lignin humic acid. At 270° C. cellulose humic acid gives a melted residue; lignin humic acid gives a sintered, and lignin, a nonsintered powder (Fig. 1).

Decomposition of Carbohydrates, Lignin and Its Derivatives by Bacteria. The opponents of the cellulose (carbohydrate) theory defend the standpoint that during the decay of plants the carbohydrate content disappears and only lignin and its derivatives remain and that therefore views based on the formation of coal and oil from carbohydrates cannot be true. This perception is certainly wrong. There is no doubt that in these earlier plants from which oil may have been derived very little lignin was present.

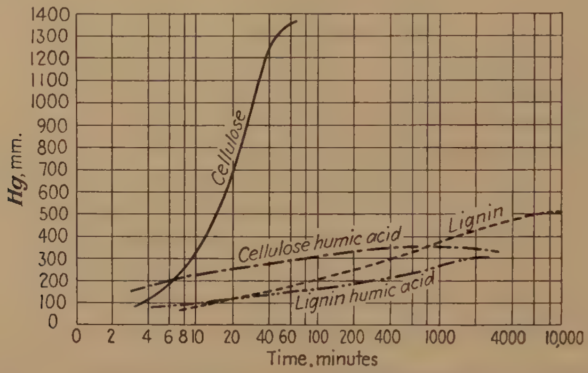


FIG. 1.—HEAT INSTABILITY OF CARBOHYDRATES AND LIGNIN.

Water-soluble carbohydrates are strongly adsorbed by peat. The adsorbed sugar material may undergo further transformation reactions in sealed enclosures (Table 2).

TABLE 2.—*Adsorption of Sugar Material*

0.50 GRAMS DRY PEAT. ADSORPTION FROM 50 C.C. X PER CENT DEXTROSE SOLUTION

X Per Cent Dextrose Solution	Glucose Adsorbed, Grams	Adsorbed Glucose in Percentage of Weight of Peat
0.5	0.028	5.6
1.0	0.046	9.2
1.5	0.06	12.0
2.0	0.07	14.0

In the beginning of the decay of plants covered with water and finely divided inorganic material like limestone, dolomite, clay, etc., which afterward form the mother rocks, a certain fermentation of carbohydrates may take place; but it is not true that under all conditions carbohydrates, especially cellulose, must disappear completely and more quickly through fermentation than lignin. It is known that some bacteria decompose lignin more quickly than cellulose.

Another point that seems to be important is that the bacteria that ferment a given substance are soon arrested in their action by the end products of the fermentation, as in the fermentation of sugar. Therefore, it must be assumed that in the beginning of the decomposition of the decayed plants a certain action of bacteria takes place, but this action may come to a standstill long before the whole material has been decomposed. Pure chemical reactions then follow, which are influenced by temperature and time. It may be of some interest to note that the products of a bacterial action are nearly the same as those from a pure chemical decomposition. Carbohydrates, for example, can be easily decomposed, with the production of lactic acid by bacteria and also by simple chemical means.

We have found the remarkable fact that certain bacteria that decompose cellulose rather quickly do not decompose cellulose humic acids and lignin humic acids, regardless of whether those bacteria are aerobic or anaerobic. This finding is important because it shows that after the transformation of carbohydrates into humic acids there is no further decomposition by bacteria. Those carbohydrate humic acids play a very important role as intermediate products between the carbohydrates, asphalt, and crude oil.

The thermoinstability of carbohydrates probably somewhat parallels the ease of decomposition of carbohydrates by the action of the bacteria. Fructose, dextrose and maltose are much more easily fermented by bacteria than starch. Starch can be decomposed much more easily than cellulose.

Decomposition of Carbohydrates and Lignin by Heat and Pressure.—We imitated geochemical conditions that existed during the formation of oil, asphalt and coals by studying the decomposition of cellulose and other carbohydrates and their derivatives, such as cellulose humic acid, and of lignin and lignin humic acid, under the influence of heat and pressure in neutral and alkaline medium.

TABLE 3.—*Cellulose Heated at 250° C. in Closed Glass Vessels*

Charging Density, Grams per C.C.	Time of Heating, Min.	Carbon in Final Product, Per Cent
0.032	130	45.5
0.1	130	53.0
0.2	130	67.5
0.207	130	68.0
0.65	130	70.5
0.654	72	67.5

Geological conditions of the transformation process can be approximated by putting the material to be treated in sealed glass capillaries, or in high-pressure bombs, so that the so-called charging density—in other words, the ratio between weight of solid material to volume—is high. In heating these capillaries or bombs at different temperatures (175° to 250° C.) from 2 hr. to several weeks, very interesting results, which show the great influence of pressure during this process, were found. These experiments throw light for the first time on the influence of pressure on the process of oil and coal formation. This influence is illustrated by Table 3, which also shows that an increase in charging density from 0.2 to 0.654 practically doubles the rate of decomposition. The same effect can be reached by increasing the temperature of decomposition 10° C.

Further experiments were carried out in sealed and nonsealed glass capillaries (Table 4). In the closed capillary practically filled with cellulose, the process of decomposition was advanced. The material under the high pressure of gases and vapors was strongly compressed. It had lost its fibrous structure and was hard and brittle. In the open capillary, where the decomposition took place without increased pressure, the material had not completely lost its fibrous structure under the conditions of our experiment. It was not as dark and no tar was found. Under the high pressure that exists in the sealed capillary or in the bomb, very important reactions take place. Through these reactions, secondary decomposition products are formed. Such experiments give more insight into the still unexplained formation of anthracite and graphite in nature.

TABLE 4.—*Cellulose Heated Eighteen Days at* 175° *C.*

Sealed capillary................	55.2 per cent C corresponds to $C_6H_{6.6}O_{3.09}$	Material has lost its fiber structure, is hard, dark, and brittle. Formation of tar.
Nonsealed capillary............	46.6 per cent C corresponds to $C_6H_{9.6}O_{4.55}$	Material shows fiber structure, lighter in color, no formation of tar.

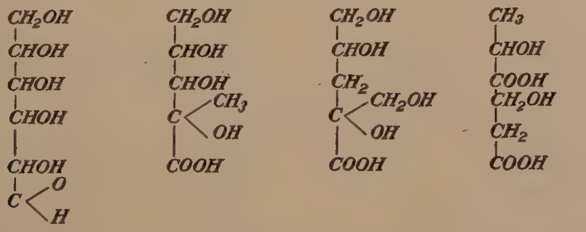
Geologists tell us that oils and coals like anthracite are formed in places where very high pressure exists. Through complete sealing and the influence of the high pressure exerted, secondary products formed through the intramolecular change react further and form products higher in carbon and lower in bound oxygen.

Influence of Alkali on Decomposition of Carbohydrates.—It is a remarkable fact that the heat decomposition of cellulose and other carbohydrates is strongly influenced by small amounts of alkali present at the beginning of the decomposition. Alkali does not change the coalification of lignin in any way except that very strong alkali splits some more methoxyl groups from the lignin molecule. The explanation of this remarkable influence of alkali may be seen in the fact that it forms nonreducing saccharin acidlike material from water-soluble carbohydrates (Fig. 2). With this alkali treatment the copper number of the solution is decreased very strongly. When saccharinic acid is coalified a semiliquid, ether-soluble material called "protoproduct" is obtained, which is identical with the bitumen of bituminous coals.

In nature, alkaline reactions can be produced very easily. The pH values of watery alkaline solutions of different rock materials are as follows: Limestone, 9.6; magnesium carbonate, 9.9; dolomite, 9.6; sodium permutite, 9.7; calcium permutite, 9.2 to 8.5; zeolite, 8.9; trass, 8.8. The reaction of water in contact with plant material, especially in the first stages of decomposition, is very important. The reaction of the rock strata plays, therefore, a great role, not only in the formation of asphalts and oils, but also in the formation of coals. Geologists agree that limestone, dolomite, and zeolites are the most important matrix for oils, asphalt and coal.

We have observed that by increasing the ratio of alkali to cellulose (not the strength of the alkali), the amount of solid substances rich in carbon formed from cellulose is greatly decreased. If a certain alkali ratio is reached, bitumen alone results, which is completely soluble in organic solvents like acetone.

Therefore, starting with fibrous cellulose, the following reactions occur: heat alone carbonizes the fiber without the formation of large amounts of soluble material; heat and water transform the material in partly water-soluble, partly insoluble material, which, upon further decomposition, gives residual coal and volatile bitumen. Small amounts of alkali reduce the amount of residual coal and form less volatile bitumen. Both actions form bituminous coals, giving either sandy or hard coke (Table 5). Rather large amounts of alkali suppress the formation of residual coal and form exclusively protoproduct identical with bitumen (Table 6).



Glucose Saccharinic acids Lactic acids

FIG. 2.—INFLUENCE OF ALKALI.

PROTOPRODUCT

The protoproducts that contain about 78 per cent C, 12 per cent H_2, 10 per cent O_2 can be made in the laboratory very easily by heat decomposition of carbohydrates in the presence of enough limestone, dolomite, magnesite or zeolite. Produced at lower temperatures, they contain less carbon and more oxygen than when produced at higher temperatures where they are more fluid. The same products can be obtained from cellulose humic acids. They contain about 30 per cent phenol carboxyl acids, 4.5 per cent phenols, and 63.5 per cent of neutral substances.

We believe that the protoproducts are the parent materials for asphalt and for crude oil. These protoproducts can be fractionated by vacuum distillation. The fractions contain phenols and neutral substances. They are fluid at first but in contact with air they become more viscous and form a kind of asphaltlike material. They have a light color which becomes darker and finally black when the material is in contact with oxygen. About 57 per cent of the carbon content of the cellulose can be converted into these protoproducts. The protoproducts can also be obtained very easily from cellulose humic acids without addition of alkali.

TABLE 5.—*Formation of Coal*

Original Material	Material Added	First Heating Temperature	Final Coalification Temperature	Final Product
1. Cellulose	H_2O	220°	320–340°	S = noncoking coal
2. Cellulose	Little alkali	220°	340°	C = coking coal
3. Cellulose	H_2O	250° or more	340°	S
4. Cellulose	Alkali	250° or more	340°	S
5. Cellulose	Acid liquid from No. 2 after heating to 220°		340°	C
6. Hydrocellulose from No. 2	H_2O		340°	S
7. Hydrocellulose from No. 2	Alkali		340°	C
8. Hydrocellulose from No. 3	H_2O		340°	S
9. Hydrocellulose from No. 3	Alkali		340°	S
10. Cellulose	Saccharinic acid	220°	340°	C
11. Cellulose	Saccharinic acid	250°	340°	C
12. Coal from Nos. 3, 4, 6, 8, 9	Bitumen (Table 6)		340°	C
13. Cellulose humic acid	Cellulose, H_2O		340°	C
14. Cellulose humic acid	Coal from Nos. 1, 3, 4, 6, 8, 9		340°	C
15. Hydrocellulose from Nos. 2, 3	Saccharinic acid		340°	C
16. Coal from Nos. 1, 3, 4, 6, 8, 9	Saccharinic acid		340°	C
17. Cellulose	Lactic acid		340°	C strongly bloated
18. Lignin humic acids	H_2O		340°	S
19. Lignin humic acids	Alkali		340°	S
20. Cellulose	½N, HCl		340°	C
21. Cellulose	H_2O, $Fe(OH)_3$		340°	S
22. Cellulose	H_2O, Cr_2O_3		340°	S
23. Cellulose	H_2O_2		340°	S

CRACKING AND HYDROGENATION OF PROTOPRODUCTS

In nature during long geological periods and through the influence of mother rocks, carbohydrates are changed into protoproduct by a kind of intramolecular combustion, with the formation of carbon dioxide, water, methane and homologues.

We can consider an internal, or intramolecular, combustion as a kind of Canizzaro reaction. The carbohydrates that are aldehydes decompose into carbonic acid and water on one hand, and into oxygen-free hydrocarbons on the other. The simplest way to represent this kind of reaction could be expressed by the equation:

$$C_6H_{10}O_5 = 2CO_2 + H_2O + C_4H_8$$

The process which really forms oxygen-free hydrocarbons from oxygen-containing carbohydrates is much more complicated than this equation expresses.

TABLE 6.—*Formation of Protoproduct*

Original Material	Material Added	Temperature, Deg. C.	Final Product B = Bitumen
24. Cellulose	Comparatively large amounts alkali reacting material, as $CaCO_3$, dolomite, NH_4OH, NH_4SH	250–330	B viscous
25. Cellulose	FeS	300–340	B viscous on heating
26. Cellulose	FeS	210–230	B viscous on heating
27. Cellulose	$FeCO_3$	210–230	B viscous on heating
28. Cellulose	Permutite	300–350	B viscous on heating
29. Cellulose	Basic rocks	300–350	B viscous on heating
30. Cellulose	H_2O, $Fe(OH)_2$	300–330	B viscous on heating
31. Cellulose	H_2O, MnO_2	315–330	B viscous on heating
32. Cellulose	H_2O, Ni-acetate	315–320	B viscous on heating
33. Cellulose humic acids	H_2O	340	B viscous on heating
34. Saccharinic acid	H_2O	340	B viscous on heating
35. Lactic acid	H_2O	340	B viscous on heating

By cracking such protoproducts at 110 atmospheres and 400° C., a material nearly free of oxygen can be obtained. Fig. 3 shows the boiling curve. There is no doubt that these rather reactive mixtures undergo the same changes at lower temperatures but during longer time intervals. We have to assume that the natural formation of oil took place at rather great depths. Under the influence of somewhat higher temperatures, the reaction yields hydrocarbons and asphaltlike residues, which probably may be found in depths that have not as yet been reached. When the protoproduct is vacuum-distilled, such asphaltlike residues remain. Table 7 shows the qualities of this asphalt made from cellulose compared with natural asphalt. Both materials seem to be of the same nature.

By the hydrogenation of these protoproducts, material that is identical with natural mineral oil is obtained. Table 8 shows the identity of these two kinds of products.

Tables 9 and 10 show that the lower boiling hydrocarbons contain aliphatic substances, some naphthenes, and a small amount of aromatics and olefines, while the higher boiling fractions contain more aromatic substances.

Pure hexane was isolated from this hydrogenation product, as may be seen in Table 11.

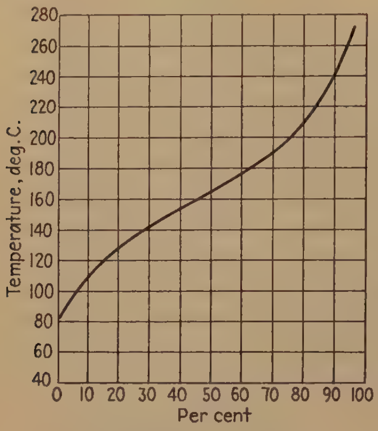


FIG. 3.—BOILING CURVE OF PROTOPRODUCTS.

We also obtained solid paraffin. Table 11 shows the data for the artificial and for natural paraffins.

TABLE 7.—*Comparison of Asphalts*

	Natural Asphalts	Asphalt Produced from Cellulose
Appearance	Dull brown black to glossy black	Glossy black-brown-black on rubbing
Fracture	Conchoidal	Conchoidal
Hardness	1–3 (Mohs)	2
Softening point	30–90°	60°
Specific gravity	1.05–1.30	1.156
Solubility	Easily soluble in CS_2, CCl_4, C_6H_6 Sparingly soluble in acetone, ether	Easily soluble in $C_2H_2Cl_4$, CCl_4, CS_2 Sparingly soluble in acetone, ether
Extraction:		
Petrol ether	Malthene 50–75 per cent	63.8 per cent
CS_2	Carbene 1–2 per cent	7.5 per cent
CCl_4	Asphaltene 1–17 per cent	20 per cent
Residue	Nonbituminous	Brown-black
Elementary analysis	86.3 per cent C, 9.3 per cent H_2O, 3.4 per cent O_2, 0.8 per cent S, 0.2 per cent N_2	89 per cent C, 7.7 per cent H_2, 3.3 per cent O_2
Fluorescence	In acetone: brown fluorescent	Yellowish brownish green fluorescent

HYDROGENATION IN NATURE

If hydrogenation reactions really occur in nature, the question of what the source of these hydrogenating substances may be has to be answered. We know that iron compounds can be found in oil strata. Bivalent iron can react, as we have shown, with oxygen-containing proto-

TABLE 8.—*Natural and Artificial Mineral Oil*

<table>
<tr><th>Property</th><th colspan="2">Natural Mineral Oil</th><th>Artificial Mineral Oil (Hydrogenation Product)</th></tr>
<tr><td>Color</td><td colspan="2">Brown fluorescent</td><td>Brown fluorescent; green to reddish brown</td></tr>
<tr><td>Olefine content</td><td colspan="2">Small, increases with increasing boiling point</td><td>Small, increases with increasing boiling point</td></tr>
<tr><td>Aromatic content</td><td colspan="2">Increases in higher boiling fractions</td><td>Increases in higher boiling fractions</td></tr>
<tr><td></td><td>Pennsylvania Per Cent</td><td>Moreni Per Cent</td><td>Up to 100° C. 10 per cent</td></tr>
<tr><td></td><td>Gasoline, 5.5</td><td>11</td><td>100°–150° C. 22 per cent</td></tr>
<tr><td></td><td>Kerosene, 13.0</td><td>39</td><td>Up to 100° C. at 16 mm., 48–61 per cent</td></tr>
<tr><td></td><td>Gas oil, 41.0</td><td>82</td><td></td></tr>
<tr><td>Naphthene content</td><td colspan="2">Maximum at 122°–150° C. (Sacchanen Wirabianz)</td><td>Maximum 100°–150° C.</td></tr>
<tr><td>Aliphatic content</td><td colspan="2">Maximum in lower boiling fractions</td><td>Maximum in lower boiling fractions</td></tr>
</table>

TABLE 9.—*Constituents of Hydrocarbons*

Oil	Specific Weight at 20° C.	Percentage of Olefine by 85 Per Cent H_2SO_4	Percentage of Aromatics by Conc. H_2SO_4 and P_2O_5	Percentage of Aliphatics	Percentage of Naphthenes
Fraction up to:					
100° C.	0.716	1.12	9.8	63	26.08
100°–150° C.	0.781	2.0	21.25	46.4	30.35
100° C. at 16 mm.	0.871	8.0	48.2		

TABLE 10.—*Constituents of Hydrocarbons*

Oil	Specific Weight at 16.5° C.	Acid Constituents by 10 Per Cent NaOH, Per Cent	Carbon-hydrogen Analysis, Per Cent		Ratio Gram-atoms H: Gram-atoms C
			C	H	
Fraction up to:					
100° C.	0.7059	2.8	85.63	14.26	2.00
100°–150° C.	0.7755	2.4	86.20	13.61	1.9
100° C. at 16 mm.	0.8671	7.2	85.19	12.00	1.69
100°–150° C. at 16 mm.	0.9602	32.0	87.76	10.09	1.38
200° C. at 16 mm.	0.9950	32.0	88.63	9.77	1.32

products with the formation of carbon dioxide and of organic material poor in oxygen. It also appears possible that hydrogen sulphide that may have been formed from gypsum acts as a hydrogenating substance, with the formation of sulphur, which, in fact, is often found in the neighborhood of oil.

TABLE 11.—*Artificial and Natural Paraffins*

Hexane	Artificial from Carbohydrates	Natural from Gasoline
Boiling point, deg. C	68–70	69
Heat of combustion, cal	11.650	11.520
Molecular weight	88.3	86.1

Paraffin	Artificial from Carbohydrates	Natural from Crude Oil
Melting point, deg. C	50.5	51.0
Molecular weight	345.7	338.4
Carbon, per cent	84.77	85.10
Hydrogen, per cent	15.74	14.89

CRACKING AND HYDROGENATION OF NATURAL ASPHALTS

We subjected natural Trinidad asphalt to the processes of cracking and hydrogenation, and obtained exactly the same end products as from the same operation applied to protoproducts. We also found that the low boiling hydrocarbons were aliphatic and the higher boiling hydrocarbons were aromatic (Table 12).

TABLE 12.—*End Products*

Fraction	$\frac{C}{H}$	S, Per Cent[a]	Unsaturated Compounds	Aromatics	Naphthenes	Aliphatics
20°–105° C.	1:2.43–2.0	0	0–1.6	0–12	0–23.3	100–63.1
106°–150°	1:1.94–1.77	0	2.2–3.5	19–32	28.6–12.0	35.4–50.2
151°–230°	1:1.74–1.62	0.1–0.09	3.5	34–44	12.0– 0.0	57.8–52.1
231°–300°	1:1.56	0.22	3.6	50	0	45.4
Over 300°	1:1.40	0.51	30	50		

[a] S in original asphalt, 4.15 per cent.

The hydrogenation products give some insight into the chemical nature of asphalts. It must be assumed that asphalts consist of aromatic nuclei with large aliphatic side chains. Through hydrogenation, a splitting off of these aliphatic side chains occurs. This is based on the fact that in the hydrogenated products a series of homologues of aliphatic hydrocarbons beginning with CH_4 and including $C_{12}H_{26}$ have been found (Fig. 4).

It seems important that practically all oils contain asphalts. Those asphalts are the incompletely transformed parent substances of crude oil. It is not justifiable to say that asphalts that contain large amounts of aromatic substances have been formed by the mild oxidation of aliphatic saturated hydrocarbons of crude oil at low temperatures. Thermodynamic reasons are against such an assumption. These asphalts were present from the beginning and were not completely transformed into oil, and afterwards only incompletely adsorbed by the mother rocks during the formation and the migration of the oil.

It may be mentioned that a material known as jet is in near relationship to our protoproduct.

OPTICAL ACTIVITY OF CARBOHYDRATES AND CRUDE OILS

Cellulose and other carbohydrates are optically active. Therefore, their derivatives can also be optically active. This corresponds with the optical activity of certain oils, which may be due also to the presence of optically active cholesterin derivatives.

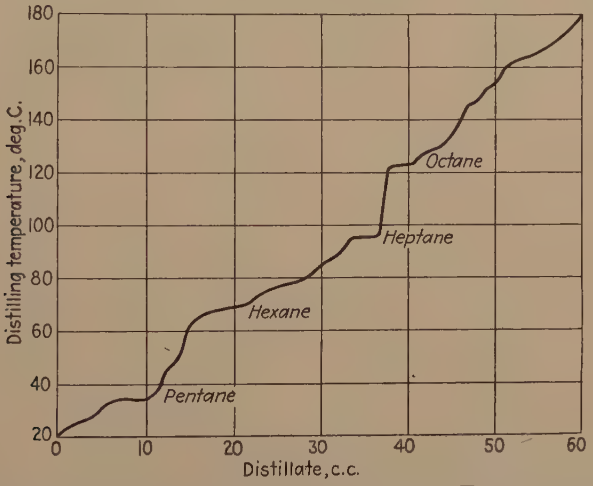


FIG. 4.—HYDROCARBONS FROM HYDROGENATION OF TRINIDAD ASPHALT.

RELATIONSHIP BETWEEN PARENT MATERIAL AND END PRODUCTS

Fig. 5 shows how all of the substances derived from carbohydrates can be put in a Gibbs triangle. The positions of cellulose, lignin, cellulose humic acids and lignin humic acids are indicated. From cellulose, or cellulose humic acids, the protoproduct can be obtained by splitting off carbon dioxide, water and lower hydrocarbons. The protoproduct in its composition is near the asphalts. The asphalts have about the same carbon content as different coals but have a lower oxygen content. From these asphalts it is a short distance to the oxygen-free hydrocarbons of different composition.

Through a combined cracking-hydrogenation process, it is possible to obtain substances from bituminous coal, which, in their composition, are not very far from crude oil because they were formed from the same parent material—carbohydrates—but in a somewhat different geochemical process.

Heat Development from the Decomposition of Carbohydrates and Lignin

It is not without interest to calculate what temperature would be reached if cellulose were transformed into oil or into coal with about

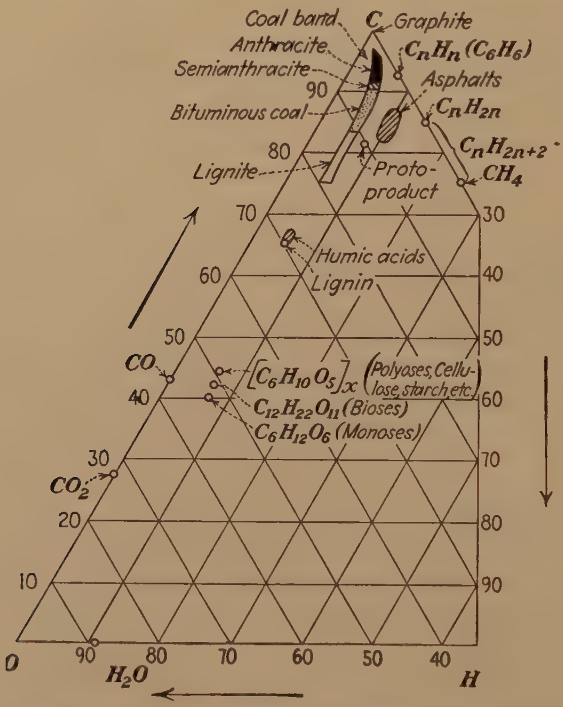


Fig. 5.—Gibbs triangle of substances derived from carbohydrates.

85 per cent carbon content. This reaction, which forms carbon dioxide, water and methane, is strongly exothermic. It has been calculated that a temperature of about 1200° to 1400° C. would be reached if the heat formed could not escape. For lignin coals an increase of only about 20° C. can be calculated. It is known that in certain localities, for example in coal mines, the temperature gradient is much higher than normal. Normally the temperature rises about 1° C. for about 33 yd. of depth. In certain oil fields and coal mines the same increase in temperature can be observed for only 16.5, or 22 yd. increased depths. We need not believe that the formation of oil and bituminous coals required many millions of years. We can assume that a kind of autocatalytic reaction

took place, with a certain incubation period followed by a rather quick reaction (Fig. 6).

ROLE OF THE MATRIX IN THE FORMATION OF CRUDE OIL AND COALS

The role of the matrix for the formation and transformation of oil hydrocarbons is of the greatest importance. The fact that very little unsaturated hydrocarbon can be found in crude oils can be explained by the action of the mother rocks. Considering any parent material whatsoever, it may be assumed that unsaturated substances are formed during its transformation into oil. A condensation of these unsaturated compounds takes place with the formation, for example, of naphthenic hydrocarbons. This may occur because of the influence of the adsorbing matrix, and perhaps, of certain catalyzing substances like vanadium compounds, which can be found very often in the plants that were the parent material. Similar condensation reactions take place in contact with the mother rocks during the migration of the oil.

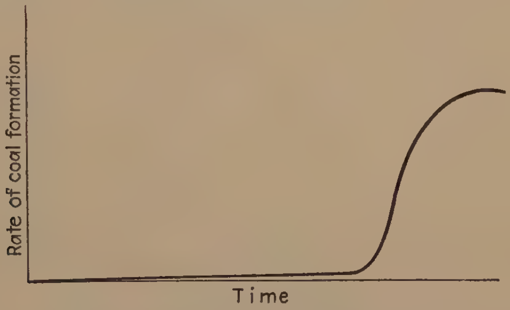


FIG. 6.—RATE OF FORMATION OF COAL.

There is no doubt that in nature the formation of crude oil from parent material through intermediary substances is still going on. In rather great depths we certainly may find semisolid and highly viscous liquid material in a stage of transformation. After having reached a lower viscosity through the process of internal combustion, and through the splitting off of aliphatic side chains from aromatic nuclei, a migration can take place whereby certain substances of high molecular weight, especially with phenol qualities, may be strongly adsorbed by the mother rocks.

The formation of crude oil, which is a hydrophobic material, in originally hydrophil mother rocks (limestone, etc.) is remarkable. It may be explained by the fact that the hydrophil mother rocks were easily wetted by watery solutions of carbohydrates, which afterwards were transformed into hydrophobic material containing some wetting material like phenols. This wetting effect by phenols and phenol carbonic acids seems to be important for the migration of largely hydrophobic liquids through hydrophilic material.

CHEMICAL DECOMPOSITION OF CARBOHYDRATES

Furan derivatives can easily be formed from carbohydrates (scheme *a*, Fig. 7). We must consider the fact that the formation of aromatic substances at low temperature must be explained. These aromatic substances are present in crude oils, in asphalts, and in bituminous coal. The difference in the content of aromatics and naphthenes in different oils may be explained by the adsorbing and condensing role of mother rocks. Fig. 7 shows that carbohydrates can be converted into aliphatic material (scheme *c*) and aromatic substances (scheme *b*). These aromatic substances, like phenols, can be formed easily at low temperatures according to scheme *b*. By the complete splitting off of water, and according to scheme *d*, a graphitelike material (type 1) could be formed from the carbohydrates. Some hydroxyl groups and other similar groups, like carboxyl groups, may be found in this graphitelike material, which is present in wood charcoal. Hydrogenation of material of this kind gives methane, which can always be observed in the hydrogenation of natural coals. The dehydration can take place also with the formation of a kind of phenolic anhydrides and naphthenic compounds with oxygen bridges, and aliphatic side chains, as may be seen in type 2, Fig. 7. We may assume that natural coal is a combination of this graphitelike type 1

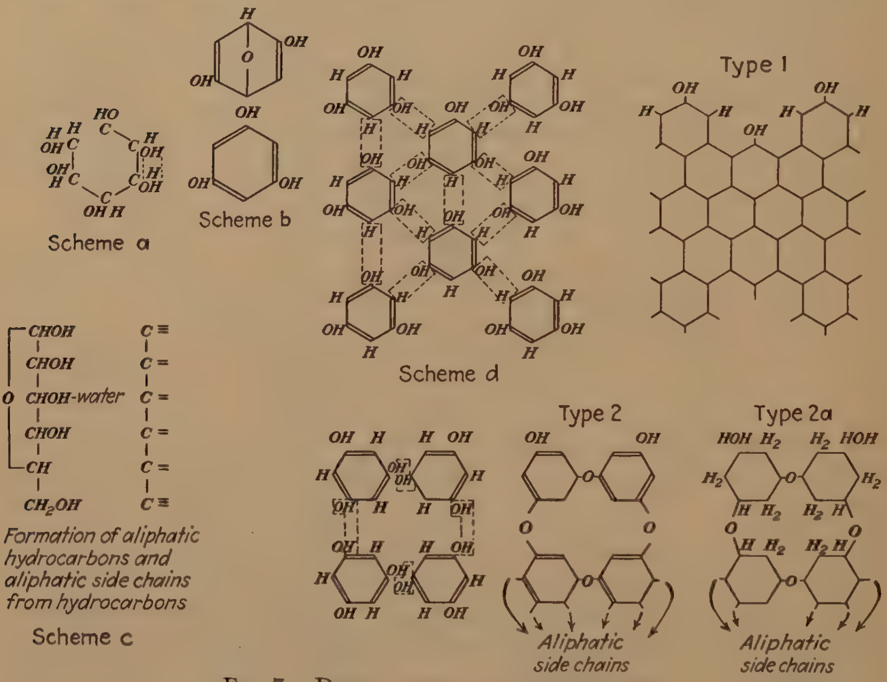


FIG. 7.—DERIVATIVES OF CARBOHYDRATES.

and the diphenyl oxide type 2 with long aliphatic side chains.* This gives natural coal a structure that resembles that of Bakelite. We know from our experiments that Bakelite, which is extremely resistant to all acid and alkaline influence, can easily be hydrogenated, and will form aromatic hydrocarbons and phenols.

Crude oil contains deoxidized aromatic and hydroaromatic material (types 2 and 2*a*) with aliphatic side chains.

Relationship between Parent Material, Intermediate, and End Products

Fig. 8 shows a kind of family tree, which combines our views concerning the formation of oils, asphalts and natural gas, and of fuseins, lignites

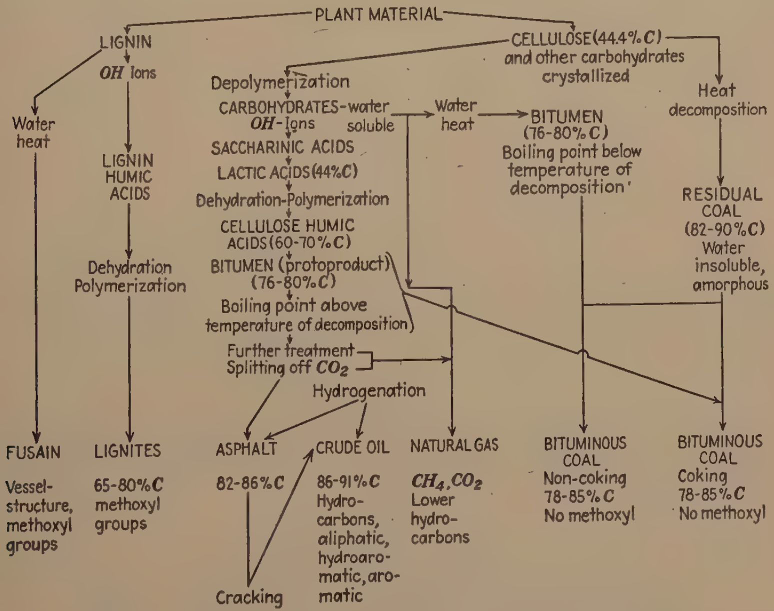


Fig. 8.—Origin of coals, oil, asphalt and natural gas.

and bituminous coals. Water-soluble carbohydrates were formed from the plant body. Under certain conditions they were separated from the original plant material. They could sink into greater depths. Under the influence of alkaline-acting mother rocks, this material could be transformed into protoproducts, asphalts, and finally into crude oil. We see that lignites and fuseins are derivatives of lignin, and that bituminous coals giving sandy or hard coke are formed from carbohydrates according to geochemical conditions in nature.

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* Besides the benzene ring compounds, compounds with several rings and side chains may be formed.

There is a possibility that several sources for oil may be considered. For statistical, chemical and geological reasons, we believe that our theory, which is based on experiment—namely, that carbohydrates and derivatives thereof are the chief parent material for asphalts and crude oils—should be given primary consideration. This theory has the great advantage that all chemical and physical facts can be easily explained, which is not true of theories like the Warren-Engler theory—that dead fish formed the parent material for these substances.

Through adsorption phenomena, large amounts of oil remain in the cavities and capillaries of the oil-bearing sands. Improved methods will help to win a large part of these important quantities, which certainly are much greater than the amounts of oil that have been extracted. It is hoped that new oil fields will be discovered. Besides the hydrogenation of coal and of carbon monoxide, and the oil procured from oil shales, there is now a possibility of producing oil from all kinds of carbohydrates, which nature puts at our disposal in enormous quantities, especially in the hot climates.

DISCUSSION

(*R. L. Huntington presiding*)

P. Weaver,* Houston, Texas (written discussion).—On the second page, Dr. Berl says: "We will show that cellulose and other carbohydrates and similar products, like algin acids and pectic acids present in organic plant material such as seaweed and algae, can be transformed in the laboratory into asphaltlike materials under the conditions that may have prevailed during their formation, in nature." The paragraph containing this sentence is headed "New Theory." I wish to direct attention to the fact that in the *Journal* of the Institution of Petroleum Technologists (February, 1932, vol. 18) there is a paper by J. E. Hackford entitled "The Chemistry of the Conversion of Algae into Bitumen and Petroleum and of the Fucosite-Petroleum Cycle." On page 114 of this article, under "Summary," there is the following statement:

"It has been shown that:—(1) Oil and bitumen are products resultant upon the prolonged acid hydrolysis of algae at low temperatures. (2) Oil and bitumen can be produced by the acid hydrolysis of the decomposition products of algae, e.g., the sugars and the calcium salts of the ethereal sulphonic esters. (3) By the acid hydrolysis of algae a bitumen is produced—algarite—similar in properties to the naturally occurring bitumen McKittrite."

It would seem, therefore, that it is scarcely correct to use a heading in Dr. Berl's paper indicating that it is an entirely new theory, because even before Hackford evidence of a similar sort had been presented regarding the formation of bitumens from algae.

Dr. Berl very interestingly comments upon the importance of the inorganic matter in which the organic matter is deposited and metamorphosed.

In connection with the possible source of oil from algae, it is just to stress that many limestones in which oil is now found, and which were considered to be possible mother rocks for oil themselves, show evidence of having been formed very largely through the agency of algae, possibly more than any other rock-building organism, and comment from Dr. Berl as to the relative importance of limestones in the transformation of original organic matter to proto-bitumen would be very instructive.

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* Geologist, Gulf Oil Corporation.

On pages 110 and 111, Dr. Berl makes a statement regarding asphalt in oil. It has, however, been demonstrated that asphalts can be formed in the laboratory by digestion with oxygen or sulphur at low temperatures with the formation of mercaptans, and possibly with the formation of other close-chain compounds, even when the original oil contained a very small amount of aromatic hydrocarbons.

I believe that Hackford has investigated this subject but I have not been able to find any publications by him giving the results of his experiments. Perhaps Dr. Berl can supply the references and can comment on that phase. The point I wish to have Dr. Berl study is whether it is quite correct to say that all of the asphalts in crude oil are primary, and whether he will not admit the possibility of formation of asphalts by the effect of oxygen and sulphur on aliphatics or on oils containing a small amount of naphthenes or aromatics.

E. Berl (written discussion).—I know the work of Mr. J. E. Hackford very well. My chief objection to this very interesting work is that it has been carried out under conditions that probably did not exist during the formation of oil. Furthermore, in London, where Mr. Hackford submitted his results before the oil technologists in January 1932, the objection was made that his oils were not very well characterized. There is practically no analysis of his products given and no physical data can be found. The objection has also been made whether large amounts of free sulphuric acid, which are necessary for his reaction, can be found in nature.

Our experiments are carried out under geochemically possible conditions. Only the temperature had to be raised to obtain higher transformation speeds. The resulting products are carefully analyzed and their properties described.

I do not know the experimental work mentioned by Mr. Weaver concerning the formation of asphalts with oxygen and sulphur at low temperatures from aliphatic hydrocarbons. According to Table 16, the asphalts contain large amounts of aromatic substances, especially of phenolic character. They cannot be formed at low temperature through the action of sulphur or oxygen on aliphatic hydrocarbons.

I realize that my standpoint concerning the relationship between asphalts and oils will find resistance, but I have no doubt that the asphalts are the parent material of oil and that they are not derived from aliphatic oil hydrocarbons by a treatment of these hydrocarbons with oxygen or sulphur at low temperature. Starting from carbohydrates with a treatment with CaS, sulphur-containing substances can easily be obtained that have asphaltlike properties. The sulphur is bound in this in phenol-like form.

Effect of Pressure upon Viscosity of Methane and Two Natural Gases

By B. H. Sage* and W. N. Lacey*

(Los Angeles and Oklahoma City Meetings, October, 1937)

In recent years there has been an increase of interest in the flow of gases at relatively high pressures. Hydrodynamic calculation of the energy losses in the flow of gases in conduits, as well as through the porous solid materials constituting natural petroleum reservoirs, requires a knowledge of the viscosity of the fluid at the pressure and temperature involved. Although there are numerous publications concerning the absolute viscosity† of hydrocarbon gases at atmospheric pressure, there appears to be little information available relating to the effect of pressure upon the viscosity of these gases.

Vogel[33] determined the viscosity of methane at 32° F. and atmospheric pressure. His measurements at 32° F. were later substantiated by the measurements of Rankine and Smith[20] at 63° and 212° F. Ishida[14] also reported values for the viscosity of methane at atmospheric pressure. Trautz and Kurz[30] measured the viscosity of propane at atmospheric pressure, from 83° to 530° F., by the use of a short capillary tube. Rappenecker[21] determined the viscosity of gaseous isopentane at elevated temperatures. Day[6] made an accurate investigation of the effect of pressure upon the viscosity of n-pentane and isopentane at pressures from 2 lb. per sq. in.‡ to the vapor pressure at 77° F. (approximately 9.8 and 13.3 lb. per sq. in., respectively). Earhart[7] reported data upon the viscosity of several natural gases measured by the long capillary-tube method.

The viscosity of air, at atmospheric pressure and 73.4° F., was measured by Harrington[9] by the rotating-cylinder method. Kellstrom[15] has recently made an elaborate investigation of the viscosity of air at atmospheric pressure. The latter work is perhaps the most accurate investigation of the viscosity of a gas that has been made.

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† All the values of viscosity reported in this paper are absolute viscosities, and are given in terms of the poise, which is a c.g.s. unit. It is realized that this is inconsistent with the other units, but was employed because of the nearly universal use of the poise for such purposes in engineering literature.

[33] References are given at the end of the paper.

‡ All pressures reported in this paper are absolute and are expressed in pounds per square inch.

Nasini and Pastonesi[17] recently investigated the effect of pressure on the viscosity of air at 57.2° F. (14° C.). These measurements were made by means of a modification of the capillary-tube method. In general they appear to be of reasonable precision and afford the only data available to the authors concerning the effect of pressure upon the viscosity of air. Boyd[2] measured the effect of pressure upon the viscosity of nitrogen and hydrogen at several temperatures at pressures as high as 2500 lb. per square inch.

Phillips[19] determined the viscosity of carbon dioxide as a function of pressure and temperature throughout the critical region. This work utilized an apparatus similar to that employed by Nasini and Pastonesi[17] in their more recent work upon air. Phillips' measurements indicated a rather large increase in viscosity with pressure, especially in the neighborhood of the critical state. At low pressures, however, the viscosity pressure coefficient of carbon dioxide does not appear to be greatly different from that of air or nitrogen. Stakelbeck[28] determined the viscosity of gaseous carbon dioxide and included measurements in the range of temperatures and pressures covered by Phillips.[19] These two sets of data show satisfactory agreement in regard to the effect of pressure at pressures below 500 lb. per sq. in. but Stakelbeck found a somewhat lower value of the atmospheric viscosity (3 per cent) than was reported by Phillips. The agreement of these two sets of determinations gives some confidence in the existing information concerning the effect of pressure upon the viscosity of carbon dioxide.

Hawkins[10] and co-workers recently investigated the effect of pressure and temperature upon the viscosity of superheated steam. They employed an apparatus similar in principle to that utilized by the authors in the present investigation. Their measurements, as reported, indicate a rather marked dependence of the viscosity upon pressure. More recently Sigwart[27] also measured the viscosity of superheated steam at elevated pressures and temperatures. The latter measurements indicate a smaller change in viscosity with pressure than was indicated by the measurements of Hawkins et al. The discrepancy between these two sets of data indicates that there is probably a serious error in the interpretation of the experimental facts in connection with one type of apparatus, since the discrepancy is many times the uncertainty of measurement involved in either case.

METHOD

The apparatus used in the investigation was a modification of that employed in previous studies[22,23] upon the viscosity of hydrocarbon liquids. In principle, the method consisted of measuring the time required for a closely fitting steel ball to roll a fixed distance in an inclined cylindrical tube, under the influence of gravity. This type of instrument was proposed by Flowers[8] and subsequently modified by Hersey[11] and Hoppler.[13]

Fig. 1 presents a diagram of the apparatus used in the present investigation. Tube *A* was machined from solid bar stock of stainless steel. The roll tube was lapped to a true cylinder with a maximum deviation in diameter of 1 × 10^{-4} in. Ball *B* was machined from the same stock and was spherical within 5 × 10^{-5} in. The diameter of the tube was 0.5002 in. and that of the ball was 0.4957 in. The tube was inclined approximately 15° from the horizontal, the angle of inclination being kept accurately constant during all measurements. The ball was released from the upper end of the tube by means of the movable contact *C*.

The roll time of the ball was determined by the elapsed time between the breaking of the upper contact *C* and the making of the lower contact *D*. This time interval was measured by means of a chronograph, which recorded the breaking and making of electrical contact between the ball and the contacts *C* and *D* respectively. The chronograph was driven by a synchronous motor, operating from the alternating-current supply of the laboratory. A comparison of the time intervals as measured by the chronograph with those by a pendulum clock indicated a probable uncertainty in the time measurements, made with the chronograph, of 0.1 per cent.

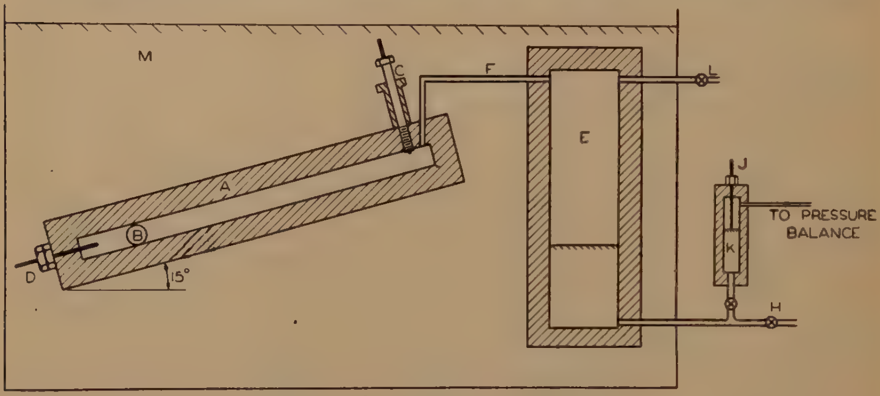

Fig. 1.—Diagram of apparatus.

Tube *A* was connected to the chamber *E* by means of the flexible steel tube *F*. This flexible connection permitted the rotation of tube *A* about trunnions located at the upper end of the roll tube, so that the ball could be returned and gently wedged under contact *C* by gravity. Chamber *E* was so arranged that mercury could be added to or withdrawn from it through valve *H*, in order to change the pressure within the instrument. The pressure existing within the viscometer was measured by a fluid pressure balance, which was connected by oil-filled tubing to the apparatus through the mercury-oil interface in the chamber *K*. This mercury-oil interface was adjusted to a constant position for each reading by changing the volume of the oil system until the mercury just touched the electrical contact *J*. The fluid pressure balance was directly calibrated against the vapor pressure of carbon dioxide at 32° F. The balance had a sensitivity of 0.5 lb. per sq. in. and it is believed that the pressures within the apparatus were known to within 1 lb. per sq. in., after correction for the hydrostatic head of oil and mercury in the connecting tubing.

The apparatus was kept at the desired temperature by means of the oil thermostat *M*. This thermostat was controlled by a mercury-in-glass regulator, and it was found that the temperature of the instrument did not vary more than 0.05° F. in the course of a series of measurements. The absolute temperature was established by means of a calibrated mercury-in-glass thermometer and was known within 0.15° F. throughout the temperature range of the present investigation.

The gases were added to the evacuated apparatus through the connecting tube *L*. To avoid contamination of the samples, the apparatus was repeatedly purged, since pressures below 0.02 in. of mercury could not be obtained readily within the apparatus, owing to the small diameter of the connecting tubing. Measurements of the roll time were made for a series of increasing pressures at a given constant temperature. The pressure was then gradually decreased by withdrawal of gas or mercury from the apparatus and another series of measurements was obtained. In general, duplicate measurements of the roll time at a given pressure and temperature agreed with one another within the accuracy of the time measurements; namely, 0.1 per cent.

CALIBRATION

A rolling-ball viscometer, such as that used in the present investigation, is not suitable for absolute measurements, and must be calibrated with fluids of known viscosity. For a discussion of the parameters involved in these calibrations the reader is referred to the work of Flowers,[8] Hersey[11] and a paper by one of the authors.[22] This work has indicated that when the flow around the ball is laminar there is a single-valued functional relation between the absolute viscosity and the rate of roll of the ball corrected for the buoyant effect of the liquid.

The instrument was calibrated with fluids; i.e., gases and liquids, of known viscosity at or near atmospheric pressure. For viscosities above 200 micropoises, Kellstrom's[15] value (183.49×10^{-6} poises) for air at 73.4° F. and a value for the viscosity of n-pentane liquid at 100° F. (1981×10^{-6} poises) were used as the primary viscosity standards. This value for n-pentane was interpolated from the measurements of Thorpe and Roger[29] which agree with a recent measurement by Tousa and Staab,[31] at 68° F. The viscosity of n-pentane liquid at 160° F. was also determined. Bridgman's[4] measurements at 167° F. were interpolated and used to aid in establishing the viscosity of n-pentane liquid at 160° F. Earlier work with the instrument has indicated that so long as the flow around the ball is strictly laminar there is a linear relation between the absolute viscosity and the parameter $\theta(\rho_0 - \rho)$ where θ is the roll time and ρ_0 and ρ are the density of the ball and of the fluid, respectively.

At viscosities below 200 micropoises a slight deviation (2 per cent at a viscosity of 100 micropoises) from this linear relation was encountered.

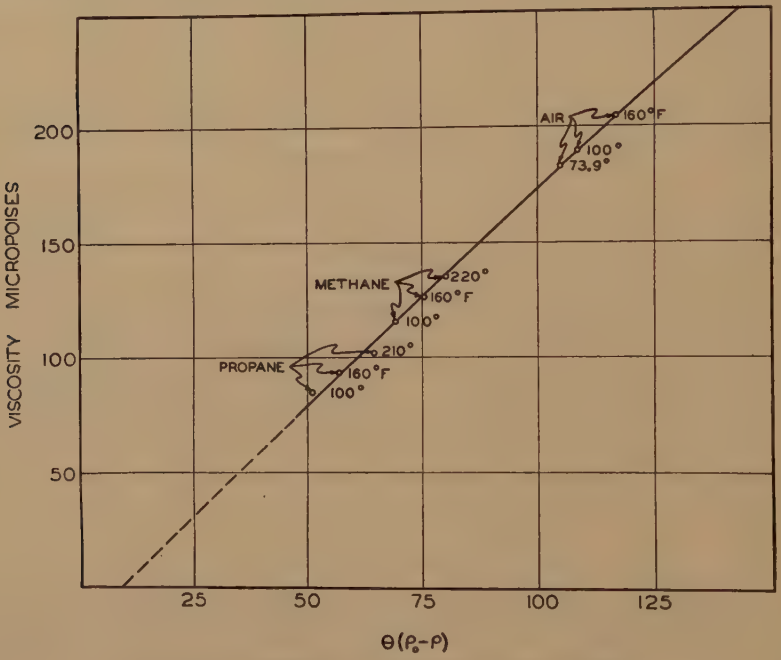

Fig. 2.—Calibration curve for laminar flow.

Therefore, the viscosity of air, methane, propane and a calculated roll time for the ball at zero viscosity, were used to establish the calibration curve (Fig. 2). The measurements of Rankine and Smith,[20] Vogel[33] and Ishida[14] upon methane were used to establish the atmospheric viscosity of this gas. The viscosity of gaseous propane at atmospheric pressure, which was determined by Trautz and Kurz[30] by the short capillary-tube method, was not of as great precision, but the data obtained for propane substantiated the calibration of the instrument as established from the data upon air and methane and the calculated roll time for zero viscosity.

The Reynolds criterion is perhaps one of the greatest aids to the study of flow processes under comparable conditions. For the present instrument it is nearly impossible to calculate a Reynolds number that is comparable with Reynolds numbers for other widely different physical arrangements. However, for this particular instrument with a given ball, it is possible to employ the ratio $\rho/\theta\eta$ in this connection where ρ as used here is the density of the fluid in grams per milliliter, θ the roll time in seconds and η the absolute viscosity in micropoises. This ratio is directly proportional to the Reynolds number for a given physical configuration of the instrument. The use of this ratio permits a comparison of the behavior of the instrument under comparable conditions of flow for a variety of fluids at a number of pressures and temperatures.

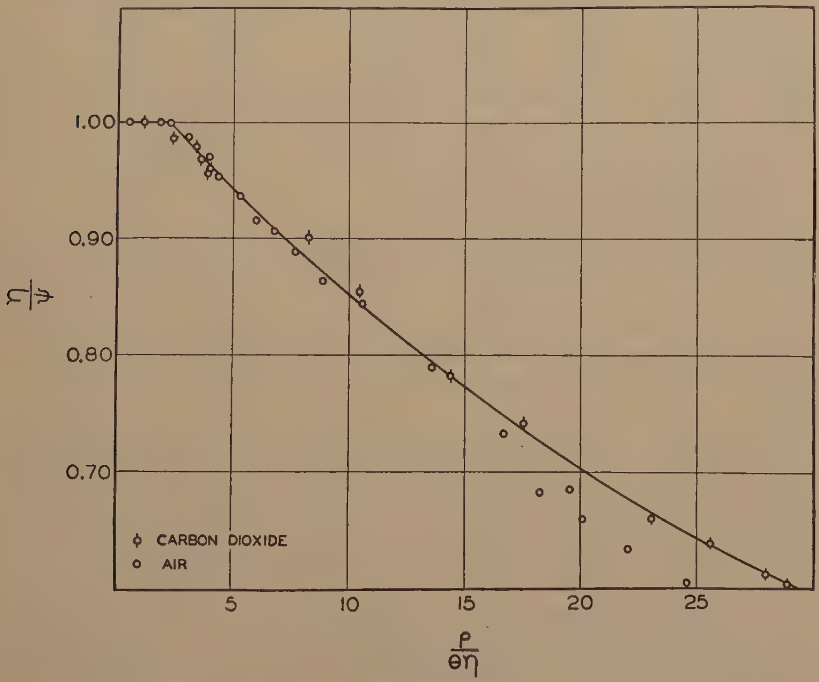

Fig. 3.—Effect of Reynolds number upon calibration of instrument.

The viscosity values of Nasini and Pastonesi[17] indicate that there will be a very large increase in the ratio $\rho/\theta\eta$ for the conditions of flow within the instrument with an increase in pressure. A similar situation is also indicated in regard to carbon dioxide. These two gases therefore afford a means of studying the behavior of the instrument at relatively high values of $\rho/\theta\eta$. In Fig. 3 is depicted the ratio of the actual viscosity η of air and carbon dioxide to the apparent viscosity ψ, as determined from the roll time, the density of the fluid and the calibration curve of Fig. 2. The data of Holborn and Schultze[12] and Amagat[1] were used to establish the relation of density to pressure for air and carbon dioxide, respectively. This ratio is presented in Fig. 3 as a function of $\rho/\theta\eta$ and indicates that for values of $\rho/\theta\eta$ below 2.5 the ratio of the actual viscosity to the apparent viscosity ψ is unity. However, at higher values of $\rho/\theta\eta$ there is an abrupt divergence between the apparent viscosity directly determined from the calibration curve (Fig. 2) and the actual viscosity. The higher values of the apparent viscosity are due to the increased resistance encountered by the ball under the turbulent conditions of flow. At values of $\rho/\theta\eta$ of approximately 30 the apparent viscosity is nearly twice as large as the actual viscosity.

The agreement of the ratio η/ψ as determined by measurements upon air and carbon dioxide at relatively low pressures indicates that the ratio $\rho/\theta\eta$ is a satisfactory index of the flow conditions existing within the instrument. At higher pressures the agreement of the data for the two gases is not as good as might be desired. The discrepancy may be due to the failure of the parameter $\rho/\theta\eta$ to correlate the flow conditions completely. On the other hand, errors in the determinations of the effect of pressure upon the viscosity of either of the gases could explain the disagreement indicated in Fig. 3.

The measurements by Boyd[2] upon nitrogen at 86° F. indicate a somewhat larger effect of pressure upon viscosity than was found by Nasini and Pastonesi[17] for air at 57° F. The divergence of the isothermal viscosity-pressure coefficient of these two sets of data increases markedly at the higher pressures. Because of the disagreement of the available data on the effect of pressure upon the viscosity of air and nitrogen, the authors believe that the data for carbon dioxide are more trustworthy and they have been utilized in the calibration of the instrument at higher values of $\rho/\theta\eta$. This procedure associates the values of viscosity reported in this paper to those determined by Phillips[19] and Stakelbeck[28] for carbon dioxide. Any errors involved in these data will be directly reflected in the values of viscosity reported here.

The viscosity of gases determined at values of $\rho/\theta\eta$ greater than 2.5 was evaluated in the following way. From the measured roll time θ and the density of the fluid ρ, the apparent viscosity ψ was ascertained directly from the curve of Fig. 2. From a knowledge of the density, roll time and apparent viscosity a value of $\rho/\theta\psi$ was calculated. If it is assumed that η/ψ is a single-valued function of $\rho/\theta\eta$ it follows that η/ψ must be a single-valued function of $\rho/\theta\psi$. From a graphic presentation of the functional relation of η/ψ to $\rho/\theta\psi$ the corresponding value of η/ψ was determined. From this value of η/ψ and the apparent viscosity already determined the absolute viscosity was obtained. This procedure eliminates the necessity of a trial solution, which would be required if Fig. 3 were used directly to ascertain the absolute viscosity under conditions of measurements where $\rho/\theta\eta$ is greater than 2.5.

Both the ball and the tube were made of the same material, therefore temperature should have only a small effect upon the calibration of the instrument. The excellent agreement between the measured increase in the viscosity of air and methane with increase of temperature at atmospheric pressure with that found by other investigators indicates that the effect of temperature upon the calibration of the instrument was smaller than the accuracy of measurement and hence has been neglected in the present work.

With the clearance between the ball and tube that was used in this work, the "slip coefficient"[18,32] does not become significant until pressures as low as 2 lb. per sq. in. are encountered and the mean free path of the molecules becomes greater than the clearances. Since no measurements are reported in this paper for a pressure below one atmosphere, it was unnecessary to make any correction on this account.

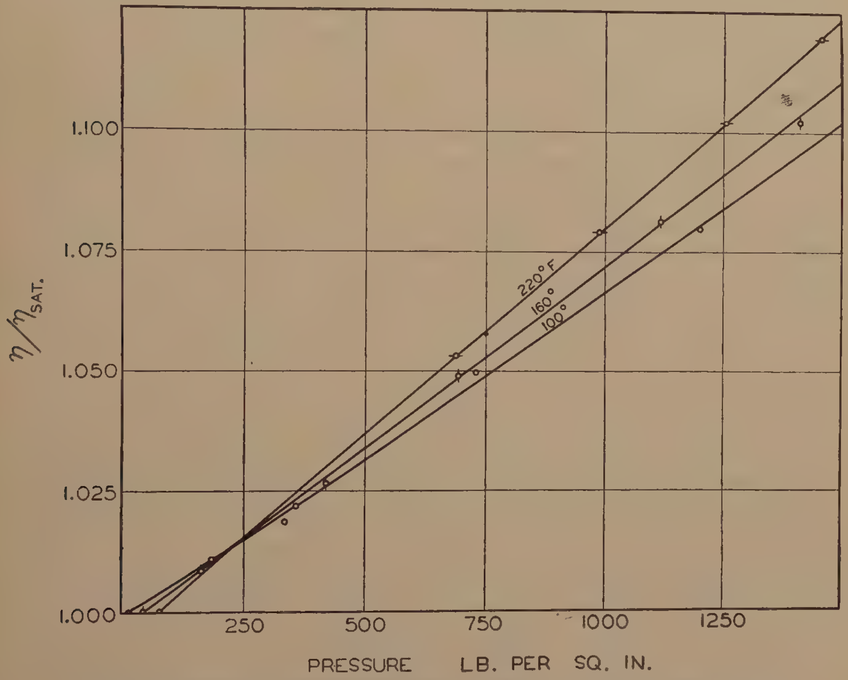

FIG. 4.—EFFECT OF PRESSURE UPON VISCOSITY OF LIQUID N-PENTANE.

The discussion above indicates that the density of the fluid, as well as the roll time of the ball, is required in order to determine the viscosity. For gases, the value of the density of the fluid encountered in this work at the highest pressure amounts only to approximately 2 per cent of that of the ball. For this reason, high accuracy is not required in the determination of the density of the gas, in order to avoid significant errors in the quantity $(\rho_0 - \rho)$.

At values of $\rho/\theta\eta$ greater than 2.5 the density of the fluid enters directly into the evaluation of η/ψ and hence into the final values of viscosity. It is therefore necessary to have accurate information available concerning the effect of temperature and pressure upon the density of the fluid in order to ascertain the absolute viscosity under such conditions of measurement that the flow around the ball is not laminar.

Since the clearance between the ball and the tube was small (0.0045 in.), any slight distortion of the ball or the tube due to pressure might cause significant changes in the calibration of the instrument. In order to ascertain the magnitude of this effect, measurements were made upon liquid n-pentane for a series of pressures at three temperatures. The density of n-pentane, as a function of pressure and temperature, which was required for the buoyancy correction was obtained from an earlier investigation[26] by the authors. The results of these viscosity measurements are presented in Fig. 4. In order to show the effect of pressure satisfactorily, the ratio of the viscosity at a given pressure to the viscosity of the saturated liquid at the same temperature was presented instead of the viscosity itself. Interpolation of Bridgman's[4] values between atmospheric and higher pressures to this pressure range indicated a satisfactory agreement between his values for the viscosity-pressure coefficient for n-pentane and those determined by the authors. For this reason, it was considered that the pressure corrections for the instrument were less than the experimental uncertainty of the measurements and, therefore, were neglected in calculating the values reported. At all temperatures below 200° F. values of $\rho/\theta\eta$ were well below 2.5, while at 200° F. a small correction for η/ψ was applied. Because of the scarcity of information concerning the viscosity of liquid n-pentane at higher temperatures, a brief résumé of the values obtained is given in Table 1. The absolute values of these results are based entirely upon the value chosen (1981×10^{-6} poises) for the viscosity of liquid n-pentane at its vapor pressure and 100° F.

TABLE 1.—*Viscosity of Liquid n-Pentane*

Temperature, Deg. F.	Pressure, Lb. per Sq. In. Abs.			
	Saturation	500	1000	1500
100	1981[a]	2043	2113	2183
160	1502	1552	1610	1653
200	1259	1305	1359	1414

[a] Values are absolute viscosity expressed in micropoises.

It is realized that the above method leaves much to be desired as a way of determining experimentally the absolute viscosity of gases at elevated pressures but it is believed that the results obtained are of sufficient engineering interest to justify their presentation as tentative values until such a time as more precise information is available. The results of the calibration of the instrument at atmospheric pressure indicated that the various experimental values were consistent within the experimental uncertainty of the reference viscosities. There is approximately 1 per cent difference between the measurements of Harrington[9] and Kellstrom[15] for air. Such discrepancies in these carefully measured values causes some uncertainty as to the accuracy of the values for the viscosity of methane and propane and air at the higher temperatures.

In general it is believed that the calibration of the instrument was made with sufficient accuracy and detail that the viscosities at atmospheric pressure were determined with an experimental uncertainty of not more than 2.5 per cent. At higher pressures where the apparent viscosity is higher than the actual viscosity, a greater uncertainty exists. If the viscosity of carbon dioxide is taken as a reference, it is believed that the calibration at values of $\rho/\theta\eta$ from 2.5 to 20 was made with an uncertainty of not more than 3 per cent, while at values greater than 20 there may be a somewhat larger uncertainty. For these reasons the viscosity of the gases reported at pressures above one atmosphere are probably known only with an accuracy of approximately 5 per cent relative to the viscosity of carbon dioxide.

MATERIALS

The methane used in this investigation was obtained from the Buttonwillow field, California. Analysis of this gas has shown it to contain 99.7 mole per cent methane, 0.3 mole per cent carbon dioxide and less than 0.02 mole per cent ethane or heavier hydrocarbons. This gas was passed over sodium hydroxide and barium perchlorate, at 500 lb. per sq. in. pressure, to remove carbon dioxide and water, respectively. The propane and n-pentane used in the calibration of the instrument were obtained from the Philgas Division of the Phillips Petroleum Corporation, Bartlesville, Okla. Their special analysis showed the propane to contain less than 0.03 mole per cent impurities, while the sample of n-pentane was found to consist of 99.3 mole per cent n-pentane and 0.7 mole per cent isopentane. The purity of these materials was further substantiated by the nearly constant values of their vapor pressures during isothermal condensation.

One of the samples of natural gas was obtained from a high-pressure trap operating at 510 lb. per sq. in. and a temperature of 148° F., in the Kettleman Hills field, California. This same gas was used in a previous investigation[24] relating to its thermodynamic properties. The gas was dried by passing it over calcium chloride at trap pressure. A fractionation analysis of this gas is given in part of Table 2, where it is referred to as "lean natural gas." This designation will be used in all subsequent references to this gas sample.

The other natural gas sample was obtained from a pumping well in the Santa Fe Springs field, in California. It was not dried and was probably saturated with water at atmospheric pressure and 80° F. Since this gas contained a considerable amount of heavier hydrocarbons the storage container and the tubing connecting with the apparatus were maintained at temperatures above 250° F. in order to avoid any condensation of the heavier constituents. A fractionation analysis of this gas is given in part of Table 2, where the gas is referred to as "rich natural gas."

TABLE 2.—*Analysis of Natural Gas Samples*

Constituent	Lean Gas[a]		Rich Gas[b]	
	Mole Per Cent	Gasoline Content[c]	Mole Per Cent	Gasoline Content[c]
Air	0.00		0.50	
Carbon dioxide	0.00		0.70	
Methane	83.19		69.74	
Ethane	8.48		9.62	
Propane	4.37		8.90	
Isobutane	0.76		1.52	
n-Butane	1.68	0.528	4.07	1.280
Isopentane	0.57	0.208		
n-Pentane	0.32	0.116		
Residues (as n-hexane)	0.63	0.258	4.95	2.029
Total	100.00	1.110	100.00	3.309
Specific gravity at 60° F. and 14.73 lb. per sq. in. referred to air	0.708		0.896	

[a] Obtained from a high-pressure trap at a flowing well, in the Kettleman Hills field, California.

[b] Obtained from a low-pressure trap at a pumping well, in the Santa Fe Springs field, California.

[c] Calculated as gallons per 1000 cu. ft.

RESULTS

The experimental results obtained for methane are depicted in Fig. 5. The necessary density data were obtained from the measurements of Kvalnes and Gaddy.[16] The curves have been dotted at the lower pressures because of the lack of a sufficient density of experimental information to establish the relation of viscosity to pressure in this region. In general the precision of measurement is several times as great as the accuracy of measurement where values of $\rho/\theta\eta$ greater than 2.5 are encountered. For this reason the details of behavior indicated by experimental points have been neglected in drawing the curves presented in

Fig. 5. It is probable that the isothermal viscosity-pressure coefficient is much smaller at pressures in the vicinity of one atmosphere than at higher pressures. However, no attempt has been made to show this effect in the figure.

The results indicate a larger isothermal viscosity-pressure coefficient at the lower temperatures which accounts for the intersection of the isotherms at the higher pressures. This type of behavior was found for carbon dioxide by both Phillips[19] and Stakelbeck[28] and is not unexpected since gases usually approximate the behavior predicted by the kinetic theory more closely at higher temperatures. The classical kinetic theory of gases indicates that the viscosity of a gas should be independent of pressure and solely a function of temperature.

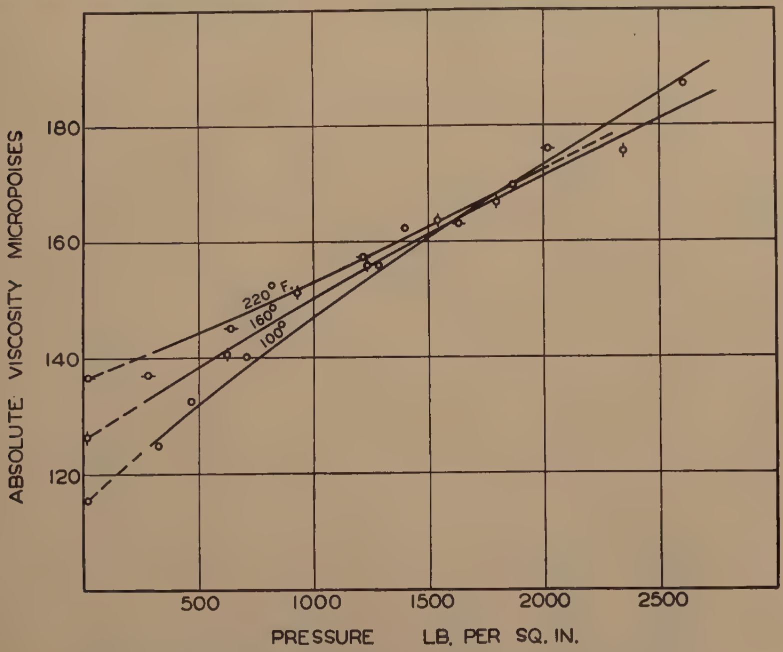

FIG. 5.—VISCOSITY OF METHANE AS A FUNCTION OF PRESSURE.

Fig. 6 presents the data for the lean natural gas. The values of density that were required in order to calculate the viscosity from the roll time of the ball were obtained from an earlier investigation[24] by the authors. The latter work indicated that this gas was above its cricondentherm[5] at all of the temperatures covered in this investigation, therefore no difficulty due to condensation was encountered. Two independent sets of measurements were made on this gas both at 100° F. and at 160° F. and the individual experimental points from the two sets of measurements at each temperature agreed with one another well within the accuracy of the present investigation. This agreement of measurements made with the instrument at different times and with different samples of the same gas is considered to be an indication of the consistency of measurement obtained. Changes in pressure as small as 2 lb. per sq. in. could be detected by the change in the measured roll time.

As with methane, the details of behavior indicated by the experimental points have been neglected in drawing the curves presented in Fig. 6. This procedure was followed because of the uncertainty of calibration for values of $\rho/\theta\eta$ greater than 2.5. There was a sufficient density of experimental data for this gas at the lower pressures to indicate that there was a smaller isothermal viscosity-pressure coefficient near atmospheric pressure than at higher pressures.

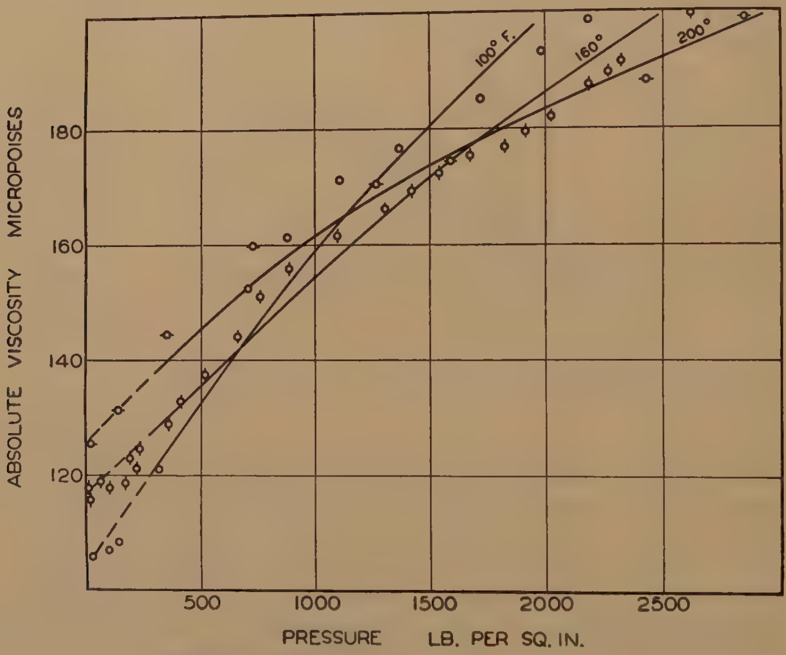

Fig. 6.—Viscosity of a lean natural gas.

The rich natural gas contained a considerably greater amount of hydrocarbons of larger molecular weight than did the lean gas sample. Since there were no satisfactory means of calculating the density of this gas as a function of pressure, the deviation of this gas from perfect gas behavior was determined at three temperatures by methods that have already been described.[25] This work was not done with great precision, since this was not necessary for the present purpose. Unfortunately, an insufficient quantity of this sample was available to permit a study of its volumetric behavior at the higher pressures. The results of this study are presented in Fig. 7. Experimental evidence obtained in the operation of the pressure-volume-temperature apparatus indicated that there may have been some condensation at 100° F. This was further substantiated by the viscosity measurements, since such irregular results were obtained at 100° F. that no values except that for atmospheric pressure have been reported for this temperature. The viscosity measurements at 160° and 200° F. are shown in Fig. 8. This gas has on the average a somewhat larger viscosity-pressure coefficient than the lean gas, but a smaller viscosity at atmospheric pressure. Owing to the small size of the sample, only a single set of measurements was made upon this gas, but it was sufficient to indicate the type of behavior that may be encountered with such wet gases.

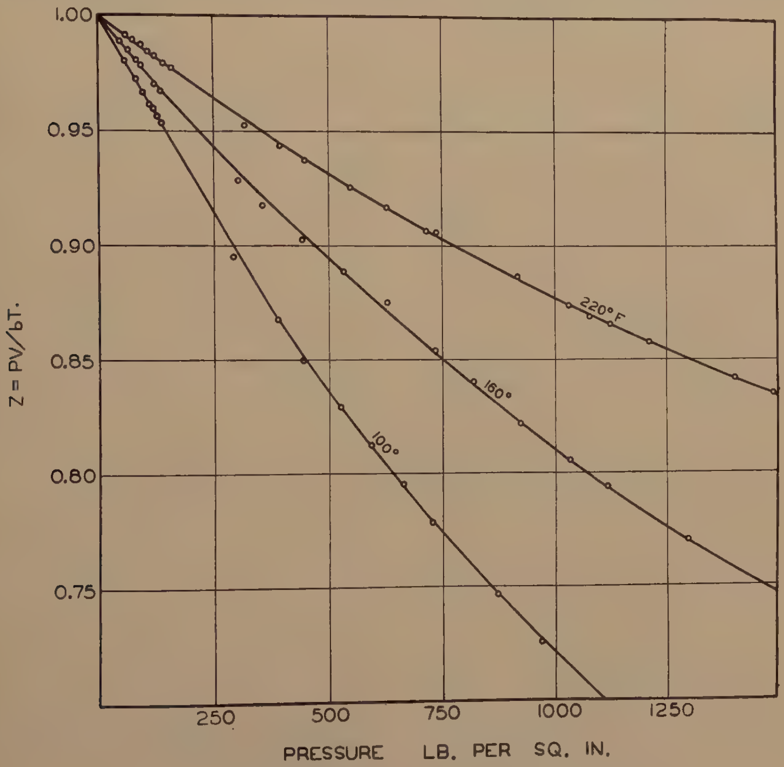

FIG. 7.—COMPRESSIBILITY OF A RICH NATURAL GAS.

Day's work[6] upon n-pentane and isopentane indicated a slight decrease in the viscosity of these materials with an increase in pressure. This type of behavior might indicate that the viscosity of hydrocarbon gases of relatively high molecular weight may reach a minimum value at a pressure not far from atmospheric pressure. However, the present work was not sufficiently detailed at these low pressures to establish definitely this type of behavior.

The rolling-ball viscometer is not considered a satisfactory instrument for the measurement of the viscosity of gases at elevated pressures, because there is not a single-valued functional relationship between the roll time and the absolute viscosity under conditions of turbulent flow. The large changes in Reynolds number with pressure that are encountered with gases make desirable the use of an instrument that avoids the possibility of turbulent conditions of flow even at the highest values of Reynolds number that are to be met.

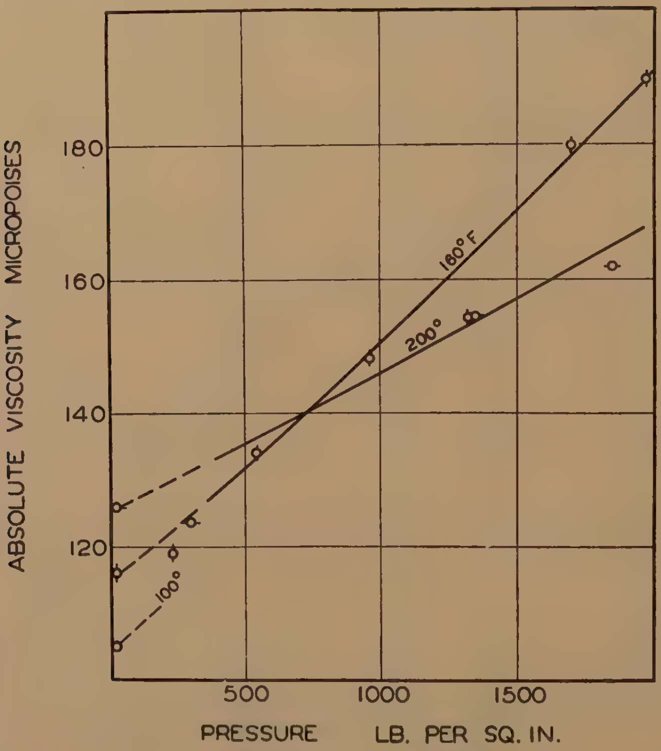

Fig. 8.—Viscosity of a rich natural gas.

The measurements of Hawkins et al.[10] upon the viscosity of superheated steam at elevated pressures and temperatures were made with a rolling-ball viscometer similar in principle to that employed by the authors in the present investigation. On the other hand, Sigwart[27] employed a modification of the capillary-tube method in his studies of the viscosity of superheated steam. The difference between these two sets of experimental data may possibly be accounted for by the existence of turbulent conditions of flow in the rolling-ball viscometer throughout a major portion of the range of temperatures and pressures covered by Hawkins' measurements. The authors did not have sufficient information available to permit a comparison of the probable Reynolds numbers existing in the viscometer employed by Hawkins with those encountered with the present instrument. For this reason it is impossible to be sure that this is the proper explanation of the divergence between the measurements of Hawkins and of Sigwart. However, conditions of high density and relatively high velocities of roll were employed by Hawkins, which are conducive to turbulence.

ACKNOWLEDGMENTS

This investigation was carried out as a part of a general program of research, relating to the physical and thermodynamic properties of hydrocarbons and their mixtures, that is being conducted by Research Project 37 of the American Petroleum Institute. The authors appreciate the cooperation and the financial support of the Institute, which have made this work possible. The sample designated as lean natural gas was obtained through the courtesy of the Kettleman North Dome Association and the Standard Oil Company of California. The sample of rich natural gas was supplied by the Union Oil Company of California, this company having also furnished the analyses reported in Table 2. The authors appreciate the interest of R. W. Ewell and E. S. Burnett, who pointed out discrepancies between the values submitted earlier by the authors and those obtained by other investigators. E. S. Burnett also called the authors' attention to references 17 and 28. The assistance of J. B. Hatcher and B. W. Dunbar in connection with the experimental measurements is acknowledged.

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Pressure Distribution in Oil and Gas Reservoirs by Membrane Analogy

By Aaron J. Miles* and Eugene A. Stephenson,† Member A.I.M.E.

(Oklahoma City Meeting, October, 1937)

The pressure distribution in a producing oil or gas reservoir has been obtained mathematically in a limited number of special cases where the boundary of the reservoirs are simple geometric figures with the wells conveniently located within them. Using some of the previous work as a basis, it can be proved that a number of additional problems of pressure distribution can be solved by use of soap film. This method is particularly applicable to a reservoir drained by a number of wells, or to a reservoir of irregular shape, or to both. Since this method obtains the pressure distribution, it also establishes the drainage boundaries of the wells.

This paper derives the analogy between the equation representing the pressure distribution in a reservoir and the equation of the deflected membrane. It also describes the apparatus and the method of operation. The experimental method is employed to solve a problem whose mathematical solution is known and the results compared. These are found to be in good agreement.

The method is applicable to any homogeneous liquid, compressible or incompressible, or to a gas, flowing in a reservoir of uniform thickness, permeability and porosity. The flow state may be either the steady state or the transient state wherein the density or pressure of the fluid in the reservoir declines at a constant rate.

Pressure-distribution Problem

Fluids encountered in the oil reservoir are compressible and expand and move toward the drilled hole where the pressure is lowest. The loss of fluid from the reservoir lowers the pressure in the more distant parts of the reservoir, permitting the fluids in these parts to expand and move toward the well. The area around the well affected by drainage is increasing continuously, and the density, pressure, and velocity of flow

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change from point to point throughout the reservoir and, in general, change at any given point with time.

In order to develop the analysis for the flow of fluids through the porous sand, the following assumptions are made:

1. The permeability, porosity and thickness of the sand are uniform throughout the area affected by the well or wells.

2. The well is a straight cylinder penetrating the entire thickness of the sand.

3. The fluid, gas or oil, behaves as a homogeneous fluid, and the velocity of flow at any point in the reservoir is directly proportional to the pressure drop per unit of length along the path of flow. According to d'Arcy's formula

$$v = -\frac{K}{u}\frac{\partial P}{\partial s} \tag{1}$$

where v is the velocity in the flow, u the viscosity, P the pressure in atmospheres, and s a distance.

4. The density of the fluid in the sand is expressed by the equation

$$\gamma = \gamma_o e^{\beta P} \tag{2}$$

Where γ and P are the density and pressure, respectively, at a point in the reservoir, and β is the compressibility of the fluid. This exponential relation for the density is an assumption adopted for convenience. For slightly compressible fluids, it reduces to

$$\gamma = \gamma_o(1 + \beta P) \tag{3}$$

when expanded by Maclaurin's theorem, and all terms in β^2 or higher are neglected, provided β is small. Furthermore, for a fluid of large compressibility, it gives a fairly close approximation over a wide range of pressures.

The equation of continuity, which is merely a mathematical statement that the rate at which the mass of the fluid flows into an infinitesimal space must be equal to the rate at which it flows out plus the time rate of increase of mass in the infinitesimal space, is expressed by the equation:

$$\frac{\partial(v_x\gamma)}{\partial x} + \frac{\partial(v_y\gamma)}{\partial y} = -f\frac{\partial\gamma}{\partial t} \qquad [4]^*$$

where v_x and v_y are component velocities of the fluid that flows parallel to the xoy plane, γ is the density, t the time and f the porosity expressed as a fraction. These velocities are obtained by dividing the quantity flowing in unit time by the gross cross-sectional area of the flow stream, and are, therefore, not the true velocities of the fluid particles in the reservoir.

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* The derivation of this equation may be found in any text on hydrodynamics.

The component velocities of the fluid, assuming a two-dimensional flow, may be expressed by the d'Arcy formula as

$$v_x = -\frac{K}{u}\frac{\partial P}{\partial x} \quad \text{and} \quad v_y = -\frac{K}{u}\frac{\partial P}{\partial y} \qquad [5]$$

where K is the permeability and u the viscosity.
Therefore

$$\gamma v_x = -\frac{K\gamma}{u}\frac{\partial P}{\partial x} \text{ etc.}$$

but from equation 2,

$$\frac{\partial \gamma}{\partial x} = \gamma_o \beta e^{\beta P}\frac{\partial P}{\partial x} = \beta\gamma\frac{\partial P}{\partial x}$$

Therefore,

$$\gamma v_x = -\frac{K}{\beta u}\frac{\partial \gamma}{\partial x}$$

and

$$\gamma v_y = -\frac{K}{\beta u}\frac{\partial \gamma}{\partial y} \qquad [6]$$

Substituting eq. 6 in eq. 4 gives

$$\frac{\partial^2 \gamma}{\partial x^2} + \frac{\partial^2 \gamma}{\partial y^2} = \frac{\beta u f}{K}\frac{\partial \gamma}{\partial t} \qquad [7]$$

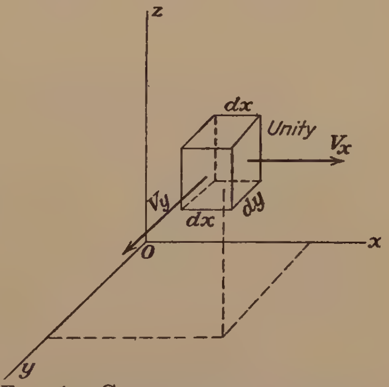

Fig. 1.—Calculation of flow of fluid into infinitesimal space.

This differential equation must be satisfied at all times and at all points in the reservoir. Where the flow is steady, $\frac{\partial \gamma}{\partial t}$ becomes zero and eq. 7 reduces to

$$\frac{\partial^2 \gamma}{\partial x^2} + \frac{\partial^2 \gamma}{\partial y^2} = 0 \qquad [8]$$

Assume that the solution of eq. 7 takes the form

$$\gamma = F(x, y, t) \qquad [9]$$

Where x and y are coordinates of the plane of the reservoir, and t, the time, is a parameter. The density γ may be represented graphically by the ordinate of a surface at time t, above the xoy plane, as shown in Fig. 2. The pressure at any given point varies as the time. Thus for $t = t_1$, γ will be represented by a curved surface above the xy plane and when $t = t_2$ by another curved surface, etc.

The pressure distribution throughout the reservoir may be obtained from eq. 9 by use of either eq. 2 or eq. 3:

$$P = \frac{1}{\beta}\left(\frac{\gamma}{\gamma_o} - 1\right) \qquad [10]$$

$$P = \frac{1}{\beta\gamma_o}[F(x, y, t) - \gamma_o] \qquad [11]$$

and from eq. 5 the resultant velocity is

$$v = \sqrt{v_x^2 + v_y^2} \qquad [12]$$

which makes an angle arc tan v_y/v_x with the x axis. This is down the direction of maximum gradient of the pressure P, and also by virtue of the relation in eq. 10, down the maximum gradient of the surface representing γ, the density.

The rate of flow through any surface such as the wall of the well may be found from the integral

$$Q = \int_S \gamma_o v_n ds \qquad [13]$$

where v_n is the velocity normal to the surface s, and the integration is to be made over the entire surface, such as the total sand face exposed in the well or any cross-sectional area through which fluid must flow to reach a group of wells.

Hence, if the density is known at all times throughout the reservoir, the pressures, velocities and the rate of production may be determined for every point in the reservoir.

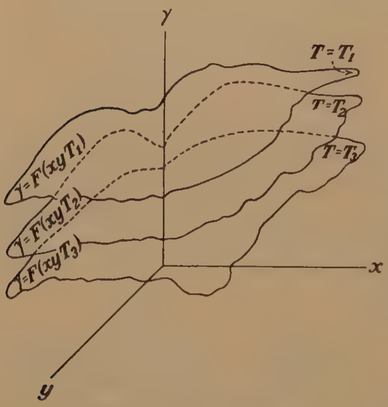

Fig. 2.—Densities.

The density of an incompressible fluid is constant, in which case eq. 4 reduces to

$$\frac{\partial v_x}{\partial x} + \frac{\partial v_y}{\partial y} = 0 \qquad [14]$$

Substituting eq. 5 in eq. 14 gives

$$\frac{\partial^2 P}{\partial x^2} + \frac{\partial^2 P}{\partial y^2} = 0 \qquad [15]$$

Since eq. 15 indicates that the pressure distribution is independent of the time, it also follows that an incompressible fluid conforms to steady state of flow, and pressure changes at any point in the system produce their effects immediately throughout the reservoir. P is now the independent variable, and a solution of eq. 15 may be expressed as

$$P = F(x, y) \tag{16}$$

P may be represented graphically as an ordinate above the xoy plane, just as was the density of a compressible fluid.

In isothermal flow of gas, the density is proportional to the pressure and may be expressed thus

$$\gamma = \gamma_o P \tag{17}$$

Substituting eqs. 17 and 5 in eq. 4 gives

$$\frac{\partial^2 P^2}{\partial x^2} + \frac{\partial^2 P^2}{\partial y^2} = \frac{2uf}{K} \frac{\partial P}{\partial t} \tag{18}$$

This is a nonlinear equation, for which a general solution is not known. But if $\frac{\partial P}{\partial t}$, the time rate of pressure decline, is constant the independent variable may be taken as P^2, and represented graphically above the xy plane just as were the density and pressures of the two previous fluids.

It is obvious that no closed reservoir can flow in a steady state. However, if the gas is flowing into the reservoir at the same rate at which it is being produced by the well, it may flow in the steady state. In this event $\frac{\partial P}{\partial t}$ of eq. 18 is zero, and the equation is then linear in P^2 and solvable for certain reservoirs and boundary conditions. Dr. Muskat[1] developed the equation representing the density distribution throughout a circular homogeneous reservoir producing a compressible fluid at a constant rate from a well at its center.

$$\gamma = \gamma_o + \frac{u\beta Q}{2\pi K}\left[\frac{3}{4} + \log\frac{r}{r_e} - \frac{1}{2}\left(\frac{r^2}{r_e^2} + \frac{4Kt}{uf\beta r_e^2}\right) + 2\sum \frac{J_o(\alpha_n r)e^{-\frac{\alpha_n^2 Kt}{uf\beta}}}{\alpha_n^2 r_e^2 J_o^2(\alpha_n r_e)}\right] \tag{19}$$

This equation contains two transients, one represented by an infinite series of Bessel functions, which disappear at a rapid rate as the time increases. Using the well spacing, reservoirs and fluid constants as found in the East Texas field, this series transient was found to be of negligible amount after a well had been flowing for 45 min. Thus the series transient may be neglected after that time. The other transient is represented by a linear term in the time variable. Hence $\frac{\partial \gamma}{\partial t}$ is a constant for all practical purposes after a well producing a compressible fluid at a constant rate has been operating for a short time.

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[1] References are at the end of the paper.

MEMBRANE ANALOGY

Imagine a homogeneous membrane stretched over a hole in a flat, thin plate and subjected to a pressure differential between the two sides. Each element of the membrane is deflected and held in equilibrium by the differential pressure p and the vertical component of the surface tension T of the membrane.

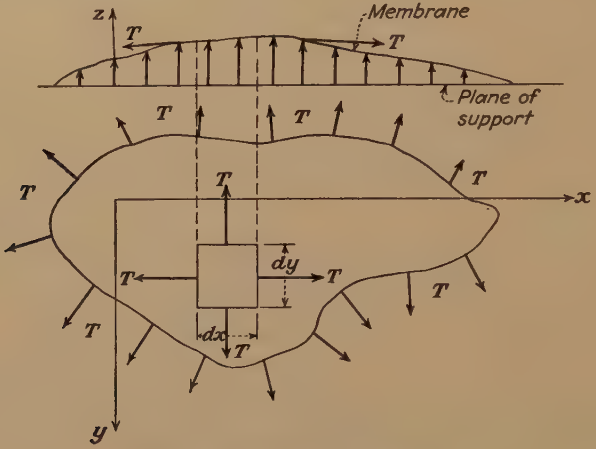

FIG. 3.—MEMBRANE ANALOGY.

The equation of equilibrium in the z direction for small deflections of the membrane is given by

$$\frac{\partial^2 z}{\partial x^2} + \frac{\partial^2 z}{\partial y^2} = -\frac{p}{2T} \qquad [20]^*$$

If the ordinate z in eq. 20 is made equal to $-\frac{Kp\gamma}{uf2T}\frac{\partial \gamma}{\partial t}$ where γ is the only variable, $\frac{\partial \gamma}{\partial t}$ is here taken as a constant, and the equation becomes

$$\frac{\partial^2 \gamma}{\partial x^2} + \frac{\partial^2 \gamma}{\partial y^2} = \frac{\beta uf}{K}\frac{\partial \gamma}{\partial t}$$

which is identical with eq. 7. Thus the deflection of the membrane represents, to some scale, the density of the fluid, if the boundary conditions of the membrane are made to correspond to the density of the fluid at the boundary of the reservoir and at the sand face of the well; that is, the hole in the plate over which the membrane is stretched must be geometrically similar to the shape of the reservoir under investigation, and the elevation of the edge of the hole above some datum plane must be to some scale equal to the density of the fluid at the boundary of the reservoir. The well is simulated by a point on the membrane pulled down to such an elevation above the datum plane as represents to the same scale the density at the sand face of the well.

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* For a derivation of this equation see G. A. Taylor and A. A. Griffith,[2] also texts on Mathematical Physics.

The membrane may be depressed at a number of points. These should be so distributed as to correspond geometrically to the position of the wells in the reservoir or field under investigation, and be placed at such elevations as will be analogous to bottom-hole flowing pressures. The latter may also all be different. It must be borne in mind that if the density is known at any point, the pressure is readily computed from eq. 2 or eq. 3.

D'Arcy's equations show that the velocity of flow in either gas or liquid is proportional to the pressure gradient, hence the lines of maximum elevations of the membrane between wells are also the boundaries of the drainage areas. In steady flow $\frac{\partial \gamma}{\partial t} = 0$, and for uniformly decreasing density $\frac{\partial \gamma}{\partial t}$ is a negative constant. The latter is in good agreement with the actual conditions in a reservoir producing at a constant rate. Contour lines on the membrane represent lines of constant pressure and constant density and the resultant movement of the fluid must be normal to these lines.

In a similar manner, it can be shown that for an incompressible liquid the ordinate of the membrane z represents to a scale the pressure in the reservoir; and for gas it represents the pressure squared.

MEMBRANE APPARATUS AND ITS USE

A photograph of the apparatus is shown in Fig. 4 and the membrane within the apparatus in Fig. 5. A flat aluminum plate 1/16 in. thick is used to hold the membrane. A hole is cut in the plate geometrically similar in shape to the reservoir to be investigated. This hole may be any convenient size from 3 to 6 in. across. The edges must be beveled one way at about 45° so that the membrane will fasten itself to this thin edge. The plate is placed over a round cast-iron box 3/4 in. deep and 10 in. in diameter and clamped in place by a cast-iron ring 2 in. deep and 10 in. in diameter. A circular glass plate, 20 in. in diameter with a micrometer depth gauge attached to it through its center, is used as a cover and may be slid to any desired position in its horizontal plane on the upper ring. The micrometer depth gauge measures in millimeters and has a sharp steel point at both its upper and lower ends.

In order to obtain a record of the elevation of the membrane at any point, the micrometer is screwed down, or the glass plate with micrometer attached is slid sideways until the lower point contacts the swinging board to which the record paper is attached (shown at upper left, Fig.

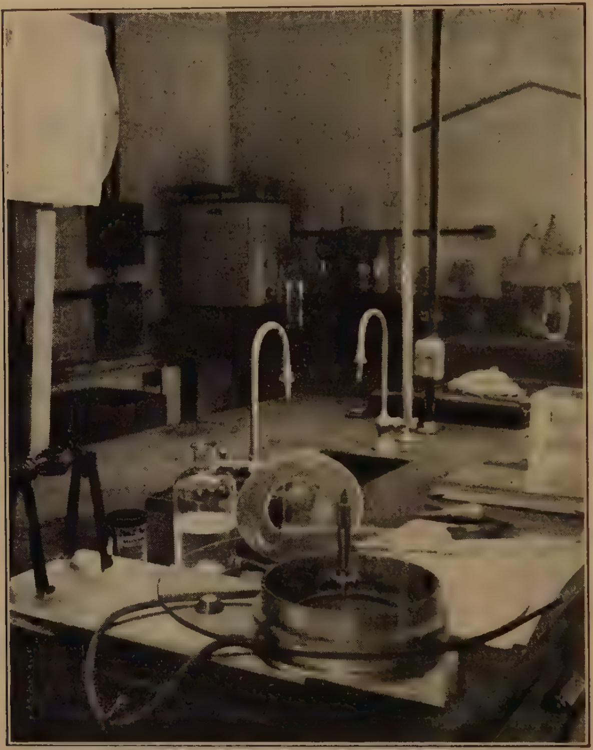

FIG. 4.—MEMBRANE APPARATUS.

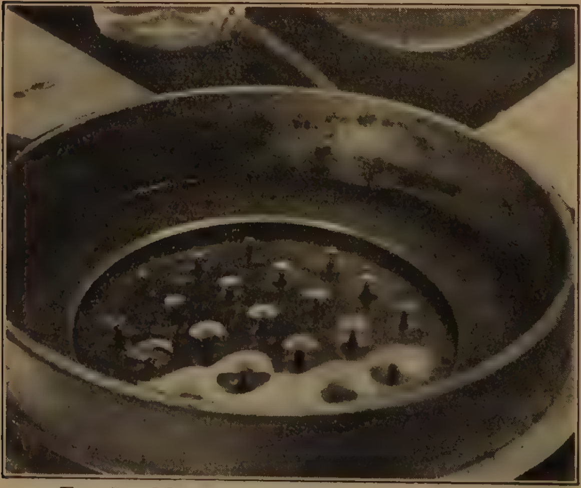

FIG. 5.—MEMBRANE WITHIN THE APPARATUS.

4), which is then brought down until the upper point of the micrometer makes a fine impression on the paper. The micrometer usually is left at a certain height and the glass plate slid around until the lower tip of the micrometer touches the membrane at a neighboring point. In this manner a contour line may be completely outlined on the contour record paper.

The membrane is made of a soap bubble* and is attached to the aluminum plate by drawing a celluloid spreader over the plate. An old kodak film makes an excellent spreader.

The edge of the aluminum plate is set at an elevation corresponding with the condition at the edge of the reservoir, while the wells are placed within the central opening at elevations corresponding to the bottom-hole flowing conditions (Fig. 5). Since it is necessary to remove the soap solution that collects on the membrane at the wells, it is desirable to use for this purpose tubes, such as hypodermic needles. Steady flow problems require no pressure differential between the two sides of the membrane, hence there must be free communication between the two sides of the aluminum plate. For other problems all points below the aluminum plate must be sealed with vacuum seal or the soap solution itself, and the necessary pressure applied to the space below the membrane by use of a balancing bottle filled with the soap solution.

Accuracy of Results

The membrane has been employed both in America and England to solve certain types of problems in the theory of elasticity and in the strength of materials. Careful study has been made[2–4] of the accuracy of the method. Comparison of the membrane analysis with such solutions as could be obtained mathematically showed less than 2 per cent error.

The pressure distribution throughout a circular reservoir producing fluid under the steady state of flow from a well at its center has been solved mathematically and is stated here for the purpose of comparison with the results obtained with the membrane method:

$$\gamma = \frac{\gamma_e - \gamma_w}{\log \frac{r_e}{r_w}} \log \frac{r}{r_w} + \gamma_w \text{ for a compressible liquid} \qquad [21]$$

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* The soap solution may be prepared by mixing 2 grams of sodium oleate and 30 c.c. of glycerin in 1 liter of distilled water. Addition of more glycerine or sodium oleate is desirable for the larger membranes. Care should be exercised in keeping the solution clean and keeping the breath and dust from the membrane. If the glass plate is kept on during the measurement, such a bubble may be touched many times and kept 10 hr. or longer without breaking.

$$P = \frac{P_e - P_w}{\log \frac{r_e}{r_w}} \log \frac{r}{r_w} + P_w \text{ for an incompressible liquid} \qquad [22]$$

$$P^2 = \frac{P_e^2 - P_w^2}{\log \frac{r_e}{r_w}} \log \frac{r}{r_w} + P_w^2 \text{ for a gas} \qquad [23]$$

where the subscripts e and w refer to the external boundary of the reservoir and well, respectively.

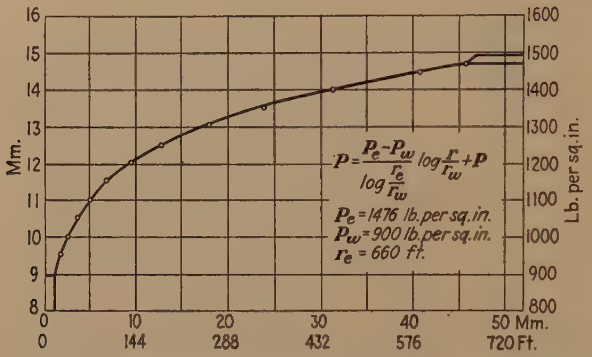

FIG. 6.—PRESSURE DISTRIBUTION ALONG A RADIAL LINE.

The top of the "well" is shown at 9, and the edge of the aluminum plate just to the left of 1500.

For a numerical example, take a well with a bottom-hole flowing pressure of 900 lb. per sq. in. and a drainage radius r_e of 660 ft. Let the pressure at external boundary be 1476 lb. per sq. in. Equation 22 gives the pressure distribution along a radial line from the well to the boundary of the reservoir and is shown as the solid curve of Fig. 6. In order to obtain the distribution along the same radial line by use of the membrane method, a circular hole was cut in the aluminum plate 91.6 mm. in diameter, which happened to be a convenient size. The edge of the plate was set in the apparatus 5.76 mm. above the top of the small tube that represents the well. Thus the elevation of the top to tube may be taken as 9.00 mm. and the edge of the plate as 14.76 mm. (Table 1). In this arrangement each 0.01 mm. represents 1 lb. per sq. in. pressure and in a horizontal direction each millimeter represents 1320/91.6, or 14.4 ft. In Fig. 6 the plotted points are the results obtained by measurement of the membrane.

TABLE 1.—*Pressure Distribution*

MILLIMETERS

r	z
1.78	9.00
2.00	9.50
2.67	10.00
3.67	10.50
5.16	11.00
7.00	11.50
9.67	12.00
13.00	12.50
18.00	13.00
24.00	13.50
31.70	14.00
41.00	14.50
45.80	14.76

A number of wells, uniformly or irregularly spaced, and with elevations corresponding to uniform or different bottom-hole pressures, can readily be studied with this same type of apparatus. Fig. 5 shows a reservoir with 21 wells. The close agreement between the theoretical analysis of pressure or density distribution and that observed by the measurement of the deflected soap film appears to provide an additional approach to the problem of reservoir drainage as well as to the location of points between wells which represent the boundaries of their drainage areas. Uniform porosity, permeability, sand thickness and steady state of flow or a steady density decline are assumed conditions.

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DISCUSSION

(R. S. Knappen presiding)

E. A. STEPHENSON.—We had difficulty in finding capillary tubes; we used cattle hypodermic needles.

T. V. MOORE,* Houston, Texas.—The paper presents new and very valuable technique for working out problems in single-phase fluids; unfortunately, in most of our fields we are interested in three-phase flow. It should give some highly interesting results. Did you ever try rubber as a membrane?

A. J. MILES.—Rubber does not work. We thought of it. Rubber follows Hook's law while the membrane follows a different law.

R. D. WYCKOFF,† Houston, Texas.—This paper presents a very beautiful analogy whereby one can see at a glance the pressure distribution is a system involving complex boundaries or multiple wells.

There appears to be a physical limitation in the models inasmuch as it would appear impractical to make the ratio of well radius to outer drainage radius as small as required for some practical cases. However, this limitation is removed if some arbitrary well radius within range of the model is used and the pressure distribution is then extrapolated to the smaller actual well radius. And none of the advantages of the visual examination of a complex pressure distribution picture would be lost by eliminating from the picture a small area immediately around the well.

A. J. MILES.—The analogy applies not only in the steady state, but also in a steady decline of pressure.

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* Production Research Division, Humble Oil and Refining Co.

† Gulf Research and Development Co.

Relation of Gas-well Spacing to Ultimate Recovery

By D. T. MacRoberts*

(Fort Worth Meeting, October, 1936)

This paper embodies the results of theoretical studies concerning gas reservoirs, especially the effect of drilling programs of various intensities upon pressure depletion and ultimate recoveries. The primary objective has been to determine the net quantity of recoverable gas that could be obtained as a result of each additional well, in comparison with the gas that might be secured from a single well ideally placed with respect to both acreage and geological structure. No method is yet known whereby the relative merits of intensive and sparse drilling can be compared experimentally; a reservoir must either be drilled closely or developed with wide spacing, but both programs cannot be conducted simultaneously. Hence, the analytical method seems to be the only approach to the problem.

While the present state of our theoretical knowledge does not offer a precise solution to the problem of gas flow in sand bodies, it takes such appropriate cognizance of the limitations of the methods used as to restrict any answer obtained to the realm of *engineering accuracy.* In solving the problem for the average gas field, it was found that practically the same answers resulted as to pressure distribution, regardless of the size of the drainage radius, even though the latter was assumed to vary from a few feet as a minimum to that of the entire reservoir as a maximum. Such limits represent extreme possibilities; therefore, the practical conditions that are associated with normal development programs, in which wells are placed in the center of tracts varying in size from 40 to 640 acres, will of necessity result in less extreme variations than those indicated in the tables accompanying this paper. Stated more concisely, *the amount of gas unrecovered at abandonment* (*of the particular field used for illustrative purposes*) *will lie somewhere between* 4.6 *and* 6 *per cent of the total original content,* no matter how intensively the field is drilled.

Gas reservoirs may be divided into two general types, those in which the energy is intrinsic, and those of which the energy is extrinsic.† The first type contains energy in the form of a compressed gas, which expands

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* United Gas Pipe Line Co., Houston, Texas.

† It is also recognized that many reservoirs have the combined characteristics of both types.

toward the well, the energy lost in friction being supplied by the expansion of the gas itself. This type of reservoir cannot be completely drained without the addition of energy from exterior sources. Some gas will still be left in the formation when the last commercial production has been obtained. The second type of reservoir, while containing gas that also expands toward the well, is surrounded by a fluid which is relatively incompressible and which gradually moves in to fill the space formerly occupied by gas. Since the energy of the gas accumulation, as indicated by the reservoir pressure, is maintained by the hydrostatic head, no loss of energy occurs over the life of the field, and a well properly situated on the structure may in time drain the entire reservoir.

The conditions under which a well may be abandoned differ, depending, among other things, upon the type of reservoir. Thus, gas-driven fields will be abandoned when the reservoir pressure becomes so low that the wells can no longer produce a sufficient quantity of gas to warrant its compression to the line pressure. Water-driven fields can be operated until the wells are progressively killed by encroaching water; eventually abandonment will be forced when the cost of keeping the wells free from water becomes excessive. The total amount of gas abandoned in a water-driven reservoir can be approximated if the shape and rate of travel of the encroaching water can be determined. In natural flooding these data are not commonly known, hence an estimate of total unrecovered gas may lack accuracy, though certain drilling patterns intended to obtain the highest recovery have been demonstrated under idealized laboratory conditions.[6,15]

From the physical characteristics of the two types of reservoirs, it is evident that in water-drive the controlling variable is area (volume of reservoir), while in gas-drive it is pressure, with the volume of the reservoir remaining constant. In order to determine the volume of gas left in a gas-driven reservoir at the time of abandonment, it is necessary to know the average pressure* existing in the reservoir at that time. As will be shown subsequently, this can be determined from the formation and flowing pressures and the pressure gradient across the reservoir under any specified flow conditions.

Throughout this paper, the following nomenclature is used:

NOMENCLATURE

Q_b, volume rate of flow measured at pressure P_b, M cu. ft. per day.
P_b, pressure base for Q_b.

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[6] References are at the end of the paper.

* There will be considerable deviation from the perfect gas laws in the early life of a high-pressure gas field, but, by the time abandonment is considered, the amount of departure will be negligible.

P_f, pressure (within the reservoir) at the drainage boundary, lb. per sq. in.
P_w, pressure at the well bore—bottom of the hole, lb. per sq. in.
P_m, mean pressure in the reservoir under any given flowing condition, lb. per sq. in.
P, pressure at any value of the drainage radius R, lb. per sq. in.
P_x, pressure at any assigned value of $R = R_x$.
R_f, radius of drainage, ft.
R, any value of drainage radius, ft.
R_x, any assigned value of R, ft.
R_w, radius of the well, ft.
R_r, radius of the reservoir, ft.
t, sand thickness, ft.
k, permeability of the formation, consistent units.
μ, viscosity of the gas, consistent units.
β, porosity, per cent.
n, C, constants observed for any particular well.
A, area drained by any producing well, sq. ft.
V_b, volume of gas left in abandoned reservoir measured at P_b, cu. ft.

EQUATIONS

The Poiseuille-Fanning equation for the radial flow of gas* is:

$$Q_b = \frac{\pi tk}{\mu P_b}\left[\frac{P_f^2 - P_w^2}{\log_e \frac{R_f}{R_w}}\right]^{\frac{1}{n}} \qquad (n = 1) \qquad [1]$$

$$Q_b = \frac{2\pi tk}{\mu P_b}\left[\frac{(P_f^2 - P_w^2)(n - 1)}{R_f^{1-n} - R_w^{1-n}}\right]^{\frac{1}{n}} \qquad (n \neq 1) \qquad [2]$$

These equations were derived analytically by Muskat and Botset[5] in 1931 and had previously been demonstrated experimentally by Pierce and Rawlins.[7] The generalized empirical formula set up by the latter is:

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* It might be well to point out that according to the classical laws of fluid flow the case $n = 1$ in equation 1 corresponds to viscous flow or Poiseuille's law; $n = 2$ corresponds to completely turbulent flow (Fanning's equation); intermediate values are states between viscous and turbulent. In application of this theory to gas production it should be remembered that the flow through consolidated sands is almost invariably viscous. This can readily be seen from the Reynolds Criterion. At extremely high rates of flow, as in open flow to the atmosphere from high-pressure wells, turbulent conditions may exist in the immediate vicinity of the well. However, this condition is not one that will in any way affect the problem under consideration here, and so far as this study is concerned only viscous flow need be assumed. The equations for turbulent flow are included solely for the purpose of indicating that the pressure-gradients and consequent average pressures were such as to preclude any possibility of their occurrence in actual production practice.

$$Q = C(P_f^2 - P_w^2)^{\frac{1}{n}} \qquad [3]$$

The coefficient C and exponent n being observed values for any particular well.

The relation between equations 1 and 3 for the condition where $n = 1$ can be seen readily when the constant C is made equal to

$$\frac{\pi t k}{\mu P_b \log_e \dfrac{R_f}{R_w}}.$$

In the seven factors, two constants appear (π, P_b). The values of t and R_w are known from the drilling or geologic data. The viscosity of the fluid, μ, can be measured experimentally. The other two variables (k and R_f) are unknown.* If it is assumed that k and R_f cannot be determined (a point that will scarcely be conceded), it is nevertheless possible to set up limits between which the actual values must lie. For example, the limits of R must necessarily be R_w and R_r.

Consequently, by making a "back-pressure" test of a gas well according to the method outlined by Pierce and Rawlins,[7] the pressure differential across the producing reservoir under any specified flow conditions can be determined. From equations 1 and 2, equations 4 and 5 may be set up to show the pressures along any radial line from the well to the edge of the reservoir:

$$P^2 = \frac{P_f^2 - P_w^2}{\log_e \dfrac{R_f}{R_w}} \log_e \frac{R}{R_r} + P_w^2 \qquad (n = 1) \qquad [4]\dagger$$

$$P^2 = \frac{P_f^2 - P_w^2}{R_f^{1-n} - R_w^{1-n}} (R^{1-n} - R_w^{1-n}) + P_w^2 \qquad (n \neq 1) \qquad [5]$$

in which P is the pressure required at any distance R to deliver gas to the well bore at rate Q.

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* While the permeability can (theoretically) be determined in the laboratory from core samples, the assumption that such results apply to whole fields may be grossly erroneous; and, since the radius of drainage enters the above equations in the logarithmic form, any small error in k causes a considerable error in R_f. Conversely, an error in the value of R_f must beof great magnitude before causing an extreme error in k.

† For any boundary conditions as to pressure and radius, any pressure gradient surface, or radial curve from the well to the edge of the reservoir has a definite form that may be represented by equations 4 and 5. Hence, any two points on the curve, such as P_w and P_f, at R_w and R_f, determine its entire characteristics, regardless of whether R is greater or less than R_f.

The average pressure in the sand under flowing conditions may be obtained by integrating expression 4 with respect to R:

$$P_m = \frac{2\pi \int_{R_w}^{R_x} R \left[\frac{P_f^2 - P_w^2}{\log_e \frac{R_f}{R_w}} \log_e \frac{R}{R_w} + P_w^2 \right]^{1/2} dR}{2\pi \int_{R_w}^{R_x} R dR} \qquad [6]^*$$

$$P_m = \frac{2}{R_x^2} \int_{R_w}^{R_x} R \left[\frac{P_f^2 - P_w^2}{\log_e \frac{R_f}{R_w}} \log_e \frac{R}{R_w} + P_w^2 \right]^{1/2} dR \qquad [7]$$

By the use of equation 4 and MacLaurin's theorem, equation 7 becomes:

$$P_m = \frac{2\lambda}{a} e^{-\frac{2b}{a}} \int_{P_w}^{P_x} P^2 \left[1 + \frac{2P^2}{a} + \left(\frac{2}{a}\right)^2 \frac{P^4}{2!} + \cdots \left(\frac{2}{a}\right)^z \frac{P^{2z}}{z!} \right] dP \qquad [8]$$

$$\lambda = \frac{2}{R_x^2}; \qquad a = \frac{P_f^2 - P_w^2}{\log_e \frac{R_f}{R_w}}; \qquad b = P_w^2 - a \log_e R_w$$

Integrating equation 8 between limits and noting that R_w is negligible in comparison with R_x and that at R_w, $P_m = P_w$:

$$P_m = \frac{2\lambda}{a} e^{-\frac{2b}{a}} \left[P^3 \left(\frac{1}{3} + \frac{2P^2}{5a} + \frac{2P^4}{7a^2} + \frac{4P^6}{27a^3} + \cdots \right) \right]_{P_w}^{P_x} \qquad \text{When } n = 1 \qquad [9]$$

While this series converges, the rate of convergence is small and is of no practical use in calculation. Since it is evident that the pressure gradient will be concentrated at the well bore, we can make an approximation of the average pressure (which should be practically identical with the exact figure when $R_x = \frac{R_f}{10}$) by determining the integral along the line $R_w - R_x$. Under this assumption, equation 4 integrates to:

$$P_m^2 = \frac{\frac{P_f^2 - P_w^2}{\log_e \frac{R_f}{R_w}} \left[\int_{R_w}^{R_x} \log_e R dR - \int_{R_w}^{R_x} \log_e R_w dR \right] + \int_{R_w}^{R_x} P_w^2 dR}{R_x - R_w} \qquad (n = 1) \quad [10]$$

Integrating between limits as before:

$$P_m = \left[\frac{(P_f^2 - P_w^2)}{\log_e \frac{R_f}{R_w}} (\log_e R_x - 1 - \log_e R_w) + P_w^2 \right]^{1/2} \qquad (n = 1) \quad [11]$$

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* See page 156.

Equation 5 may, when $n = 2$, be integrated directly as:

$$P_m = \frac{2}{R_x^2}\,{}_{R_w}^{R_x}\!\left[\frac{2bR + a}{4b}\sqrt{bR^2 + aR} - \frac{a^3}{8b^{3/2}}\log_e\left(\sqrt{bR^2 + aR} + \frac{2bR + a}{2b^{1/2}}\right)\right] \qquad [12]$$

Where

$$a = \frac{P_f^2 - P_w^2}{R_f^{1-n} - R_w^{1-n}}$$

$$b = P_w^2 - aR_w^{-1}$$

Since this equation is inconvenient for calculation, we may here use the approximation:

$$P_m^2 = \frac{\dfrac{P_f^2 - P_w^2}{R_f^{1-n} - R_w^{1-n}}\left[\int_{R_w}^{R_x} R^{1-n}dR - \int_{R_w}^{R_x} R_w^{1-n}dR\right] + \int_{R_w}^{R_x} P_w^2 dR}{R_x - R_w} \qquad (n \neq 1) \quad [13]$$

$$P_m = {}_{R_w}^{R_x}\!\left[\frac{P_f^2 - P_w^2}{R_f^{1-n} - R_w^{1-n}}\left(\frac{R_x^{1-n}}{2 - n} - R_w^{1-n}\right) + P_w^2\right]^{1/2} \qquad 2 > n > 1 \quad [14]$$

$$P_m = {}_{R_w}^{R_x}\!\left[\frac{\dfrac{P_f^2 - P_w^2}{R_f^{-1} - R_w^{-1}}\left(\log_e R_x - \dfrac{R_x}{R_w}\right) + R_x P_u^2}{R_x}\right] \qquad n = 2 \quad [15]^*$$

A well closed in will have a radius of drainage equal to R_w. As the well is opened the radius of drainage expands from R_w and at any instant has the value R_x. This value is not known from test data. In the absence of interfering wells, it may be assumed that, in time, R_x will approach the boundary of the reservoir, which is also the absolute upper limit. The lower limit of R_x has no such definite value once the well is opened, but we will assume that 104 ft. (one-acre spacing) is the minimum under test.

It should be kept in mind that the assumption of a drainage radius equal either to the reservoir radius or to 104 ft. is not as artificial as it appears. The actual value must lie somewhere between these limits, and calculations based on these limiting values may indicate that certain conclusions will be true for all intermediate values.

From a practical standpoint the flowing life of a gas well is limited to that time during which sufficient gas can be produced at a high enough pressure and at a cost not greater than the value of the gas. At this abandonment time, certain pressure differentials exist across the reservoir, dependent upon the spacing, and the volume of gas abandoned will be:

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* The writer does not intend to imply that the integrations 11, 14 and 15 are solutions, in the rigorous sense, of equations 4 and 5. They are merely more convenient methods of approximating the exact values of equations 9 and 12 than is graphical integration. Graphical integration of the specific case to be discussed for the conditions $R_f = 104$, $R_x = 104$, $n = 1$ gives a value of P_m only 2.7 per cent greater than the approximate solution of equation 11; while an exact solution for similar conditions from equation 12 gives identical results, to four significant figures, with the approximation 15.

$$V_b = \frac{t_1 A_1 \beta_1 P_{m_1}}{P_b} + \frac{t_2 A_2 \beta_2 P_{m_2}}{P_b} + \cdots = \sum \left(\frac{t A \beta P_m}{P_b} \right) \qquad [16]$$

A being the area drained by each producing well, and β the porosity of the formation. It is also assumed that these areas are equal and the formation is homogeneous. Hence, since P_m has been determined to be the expression shown in equation 11, the total volume of gas abandoned becomes, for uniform well spacing and a homogeneous formation:

$$V_b = \sum \left[\frac{t A \beta \left(\frac{P_f^2 - P_w^2}{\log_e \frac{R_f}{R_w}} [\log_e R_x - 1 - \log_e R_w] + P_w^2 \right)^{1/2}}{P_b} \right] \qquad (n = 1) \quad [17]$$

Application to a Specific Example

The specific field to be considered has the following characteristics:

Depth of producing formation.....	4,800 ft.
Sand thickness..................	19 ft.
Porosity........................	23 per cent
Area............................	11,060 acres
Initial formation pressure........	1,950 lb. per sq. in. absolute
Initial reservoir contents..........	278,000,000 M cu. ft.*
Gravity of gas.....................	0.62

* Deviation from Boyle's law not considered.

A typical producing well in this field was tested and found to have a characteristic equation of:

$$Q = 0.01698(P_f^2 - P_w^2)^{1.00} \qquad [18]$$

Q being measured at 14.7 lb. per sq. in., P_f and P_w in pounds per square inch absolute. The diameter of the well bore is 6 in.

The abandonment conditions are assumed to be:

Delivery capacity per well...............	100 M cu. ft. per day
Well-head pressure......................	64.7 lb. per sq. in. absolute

The bottom-hole pressure under these conditions would be 71.4 lb. per sq. in. abs., and from equation 18 P_f is found to be 104.8 lb. The two limits previously mentioned may now be introduced, and the assumption made that the abandonment pressure exists either at R_f = 104 ft., or at

TABLE 1.—*Pressures at R_x, and Average Pressures within the Area Bounded by R_x*

R_x, Ft.	When R_f = 104 Ft.		When R_f = 12,384 Ft.	
	P_x	P_m	P_x	P_m
104	104.8	100.0	91.5	88.5
330	110.0	105.5	94.9	92.0
660	113.1	108.7	96.9	94.0
933	114.6	110.2	97.9	95.0
1,320	116.0	111.8	98.8	96.0
1,867	117.5	113.2	99.8	97.0
2,640	118.9	114.7	100.7	98.0
12,384	125.1	121.1	104.8	102.2

TABLE 2.—*Volume of Gas Unrecovered at Abandonment under Various Spacings*

Acres per Well	R_x	R_f = 104 Ft.		R_f = 12,384 Ft.	
		Volume, M^2 Cu. Ft.	Percentage of Original Volume	Total Volume, M^2 Cu. Ft.	Percentage of Original Volume
1	104	14,470	5.21	12,766	4.59
10	330	15,248	5.48	13,265	4.77
40	660	15,704	5.65	13,552	4.87
80	933	15,919	5.73	13,696	4.93
160	1,320	16,140	5.81	13,836	4.98
320	1,867	16,343	5.88	13,979	5.03
640	2,640	16,557	5.96	14,119	5.08
11,060	12,384	17,467	6.28	14,716	5.29

TABLE 3.—*Gain in Ultimate Recovery of Spacing A over Spacing B*
MILLIONS OF CUBIC FEET

Spacing A, Acres per Well	Spacing B, Acres per Well, R_f = 104 Ft.						
	10	40	80	160	320	640	11,060
1	778	1,234	1,449	1,670	1,875	2,087	2,997
10		456	671	892	1,097	1,309	2,219
40			215	436	641	853	1,763
80				221	426	638	1,548
160					205	417	1,327
320						212	1,122
640							910

R_f = 12,384 ft.* The pressure distribution at various distances R_x, and the average pressures are shown in Table 1. Table 2 shows the volume of gas that will be abandoned in the reservoir under various spacing programs. Tables 3 and 4 compare the effects of the various spacing programs upon gross recovery and recovery per well.

There seems to be little question about the conclusions that must be drawn from this analysis. *Intensive drilling in gas reservoirs will increase the ultimate recovery but slightly. Even under the approximate solution given, a single well on each acre, or* 11,060 *wells for the entire field, would recover only* 2,997,000 *M cu. ft. more gas* (1.08 *per cent of original contents*) *than would be recovered if but a single well were drilled in the entire field.*† (See Table 2.)

TABLE 4.—*Gain in Ultimate Recovery for Each Additional Well under Spacing A over Spacing B*

THOUSANDS OF CUBIC FEET

Spacing A		Spacing B, Acres per Well. R_x = 104 Ft.						
Acres per Well	Wells Required	10	40	80	160	320	640	11,060
1	11,060	78	114	133	152	170	189	271
10	1,106		549	693	860	1,023	1,202	1,905
40	276			1,558	2,106	2,649	3,293	6,411
80	138				3,203	4,096	5,273	11,299
160	69					5,942	8,019	19,515
320	34						12,471	34,000
640	17							56,875

Any refinement of the mathematics presented above will only serve to accentuate the insignificance of this additional recovery. Nor will such a recovery be net gain. Gas will be required for drilling, operating and testing the wells, and under normal field conditions, will come from the reservoir that is being developed. It is evident therefore that intensive drilling for the purpose of increasing the ultimate recovery will defeat itself at the point where the gas used in drilling, operating and testing the well exceeds the increase in ultimate recovery that results from the intensive drilling.

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* The assumption of two drainage radii (which implies two values of the permeability) can be substantiated on these grounds: assume the field to be drilled to its maximum density (one well per acre) and a test made on the central well, R_f = 104 ft. If other wells are closed in and the spacing thereby varied, the gradients will conform to those given in Table 1. In the field with only one well, the value of R_f is 12,384 ft. If the field is drilled to various densities the gradients will conform to those in the second part of Table 1. The fact that one test was used for both these examples does not invalidate the conclusions, especially since the actual conditions governing the specific example were approximately halfway between the extremes illustrated.

† The writer wishes it expressly understood that this discussion must not be considered as a proposal to drill but a single well in gas reservoirs. The number of wells to be drilled in a particular field should be determined by the demands of the various pipe lines that serve the field. Any drilling in excess of such requirements is wasteful, unnecessary and uneconomic.

ACKNOWLEDGMENTS

The writer wishes to express his sincere appreciation to Dr. E. S. Burnett, of the U. S. Bureau of Mines, for his pertinent and helpful criticisms of the manuscript, and particularly to Dr. Eugene A. Stephenson, of the Missouri School of Mines and Metallurgy, who read and corrected the original and final drafts of this analysis. Thanks are also given to Dr. A. J. Miles, of the Missouri School of Mines and Metallurgy, who has carefully checked the mathematical derivations.

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APPENDIX

A more direct solution of equation 6 may be easily obtained. Consider a function $\Phi = f(R)$ so that:

$$\Phi = \frac{\Phi_1 - \Phi_2}{\log_e \dfrac{R_1}{R_2}} \left(\log_e \frac{R}{R_2} \right) + \Phi_2$$

$$R = R_1; \qquad \Phi = \Phi_1$$
$$R = R_2; \qquad \Phi = \Phi_2$$

Integrating, we have:

$$\Phi_m = \frac{2}{R_x^2} \int_{R_1}^{R_x} R \left[\frac{\Phi_1 - \Phi_2}{\log_e \dfrac{R_1}{R_2}} \log_e \frac{R}{R_2} + \Phi_2 \right] dR$$

which becomes:

$$\Phi_m = \frac{\Phi_1 - \Phi_2}{\log_e \dfrac{R_1}{R_2}} \left(\log_e \frac{R}{R_2} - \frac{1}{2} \right) + \Phi_2$$

when

$$R_1 >> R_2 \text{ and at } R = R_2, \ \Phi_m = \Phi_2$$

Letting $\Phi = P$, we have the average pressure in a radial channel flowing an incompressible fluid; if $\Phi = P^2$ we have the *average square* of the pressure in a radial channel flowing a gas. Evidently, for the particular condition discussed in the paper:

$$\left[\frac{P_f - P_w^2}{\log_e \dfrac{R_f}{R_w}} \left(\log_e \frac{R}{R_w} - \frac{1}{2} \right) + P_w^2 \right]^{1/2} >$$

$$P_m > \left[\frac{P_f - P_w}{\log_e \dfrac{R_f}{R_w}} \left(\log_e \frac{R}{R_w} - \frac{1}{2} \right) + P_w \right]$$

This shows that for a quite close approximation the average pressure in a radial channel can be taken as the pressure at 6/10 the drainage radius, and in any event it must lie between 50 and 60 per cent of the radius of drainage.

DISCUSSION

(*T. V. Moore presiding*)

E. S. BURNETT,* Washington, D. C. (written discussion).—Mr. MacRoberts' paper represents considerable study and effort on the author's part and affords a concrete picture of a situation long recognized, but perhaps not fully appreciated heretofore.

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The factor $(n - 1)$ of his equation 2 should be $(1 - n)$, for with $2 > n > 1$, the denominator of the bracket of that equation is negative.

The author bases his tabulated comparisons upon the assumption that equation 18, found to hold for a typical producing well in a certain field, would also hold for any and all wells that might have been drilled in the field, regardless of the spacing.

Thus a horizontal comparison of his P_x values in Table 1 with his assumed constant P_w of 71.4 lb. per sq. in. absolute shows on the average a 63 per cent greater pressure drop when $R_f = 12{,}384$ ft. for the same flow over identical distances from the well than when $R_f = 104$ ft. This discrepancy corresponds to a maximum variation in permeability k, of the order of 4 to 7, and to a different value of k for the field for each spacing assumed. Rather than to make such an assumption, which seems untenable, it would have been better to assume some average value of permeability for the whole field and adhere to that value.

With an average k, equation 18 corresponds to an R_f of 1208 ft. (approximately 105.2 acres per well). The corresponding pressure distributions for the various assumed well spacings computed on this basis are then consistent in yielding identical pressure gradients over equal distances from the well bores for a given flow, as they should be. The author's remarks in the footnote on page 154 do not seem to justify the assumptions, when a consistent one could have been handled as easily. His conclusions, however, would not be affected appreciably.

The mathematical developments, equations 6, 7, 8, 9 and 12, appear superfluous, since the author immediately discards them as useless. Possibly equations 8 and 12 may be serviceable to some readers, who are interested in their mathematical exactness. To this commentator the author's approximate method of computing P_m appears to lack mathematical support, and is justified only by the comparison mentioned in the footnote on page 151. All of the P_m values of this paper are based upon assumed circular drainage areas about each well, with radii equal to one-half the spacing; they are applied to the corresponding circumscribed square areas, which are the actual drainage areas of a homogeneous structure drilled on a square pattern. Consequently all computed mean pressures, and unrecovered volumes dependent thereon, are too small by slight amounts.

Despite these inconsistencies of estimates, resulting from neglect of what the author may have considered to be unnecessary refinements of mathematics, and disregarding the time factors of depletion, Mr. MacRoberts has presented a forceful picture of the uselessness of drilling wells closer than is necessary to supply the demands on a gas field, in the vain hope of materially increasing the ultimate recovery thereby.

D. T. MacRoberts.—Mr. Burnett is incorrect in assuming that each spacing shown requires a different permeability constant. The two calculations headed $R_f = 104$ ft. and $R_f = 12{,}384$ ft. do demand different permeabilities—they are expressly stated as the limits within which the true value must lie. I see no more justification for taking the average of these limits than for using the limits themselves.

The assumption of the steady state, as is at present necessary, in itself is a more serious error than any of the matters mentioned. For that reason the P_m values are based on a circular area and are extended to the square areas by the basic assumption whereon equations 1 and 2 are set up: that there was no pressure gradient at $R > R_f$. The insignificance of this difference would not be apparent and the P_m values would appear to be extended directly to the squares.

As for the mathematics, I believe that it is necessary in a case like this to show: (1) that an exact solution does or does not exist; (2) that it cannot be applied in the particular case; (3) that a satisfactory approximation can be made. The validity of an approximation, if the expression means anything, depends solely upon the degree to which it approximates. Thus for $R_f = 104$ ft., $R_x = 104$ ft. under Table 1 we can derive:

Gauss law of the mean	$P_m = 101.7$
Average "potential" as given in this note	$P_m > 102.0$ $P_m < 102.4$
Graphical integration	$P_m \cong 102.7$
Equation 11	$P_m = 100.0$

Since the value 102.3 lb. is more nearly correct, the error in equation 11 is 2.2 per cent. The net effect of the approximation used is to indicate a slightly higher recovery for each additional well than would actually be obtained.

The time element of depletion is to be covered by a new paper this year.

Application of Vaporization Equilibrium Constants to Production Engineering Problems

By Donald L. Katz,* Junior Member A.I.M.E.

(Oklahoma City Meeting, October, 1937)

The equilibrium constants developed by Souders, Selheimer and Brown[17] have been very useful tools in predicting vapor-liquid equilibria during the past five years. Their equilibrium constants were computed by assuming ideal solutions and recognizing the deviations of vapors from ideal gas laws. The same fundamental concepts were used by Lewis and co-workers[8] for predicting vaporization phenomena by means of fugacities.

The equilibrium constant is defined by equation 1:

$$\frac{y}{x} = K \qquad [1]$$

in which K = equilibrium constant,
y = mol fraction of a constituent in the vapor phase,
x = mol fraction of the constituent in the equilibrium liquid phase.

The equilibrium constants are a function of temperature and pressure and might be considered as replacing the ratio of the vapor pressure to the total pressure of Raoult's law. They may be used to compute the vapor or saturation pressure of a liquid or the dew point of a vapor for any pressure or temperature from the analysis of the mixture much as Raoult's law is used. Likewise, the quantity of a mixture that will vaporize at any equilibrium temperature and pressure and the composition of the vapor and liquid may be calculated.

The purpose of this paper is to review the available equilibrium data of interest in petroleum production, to discuss the auxiliary physical properties of the hydrocarbons, and to present typical uses of the equilibrium constants. The particular applications chosen are the computation of the results of stage separation of crude oil and natural gas, the calculation of a pressure-volume curve of a crude oil-natural gas mixture, and information gleaned from a consideration of reservoir equilibria.

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[17] References are at the end of the paper.

EQUILIBRIUM DATA

Conditions encountered in crude-oil production are in the range from atmospheric pressure to above 3000 lb. per sq. in. and from about 30° to above 200° F. Under these conditions, the primary vaporization occurring in the natural mixtures consists of nitrogen, methane, ethane, propane, etc., through the compounds predominant in natural gasoline such as heptane or octane. The initial equilibrium constants[17] did not cover the desired pressure range and neither Brown's equilibrium constants nor Lewis' fugacities were of the desired accuracy in crude-oil mixtures for methane, the most prolific compound. Therefore only recently have satisfactory equilibrium data been available with the presentation of the experimental equilibrium constants obtained in the laboratories of Phillips Petroleum Company.[3]

Equilibrium constants were determined on a naturally occurring mixture of crude oil and natural gas at 40°, 120°, and 200° F. at pressures from atmospheric to 3400 lb. per sq. in. The vapors and liquids in equilibrium were analyzed by low-temperature fractionation for methane, ethane, propane, butanes, pentanes, hexanes and heptanes and heavier, the analyses providing the values of y over x or K for the constituents. Fig. 1 shows the data obtained at 120° F. as points with the smoothed curves inserted. Similar data were obtained at 40° and 200° F. and general plots were made of equilibrium constants versus temperature (−30° to 270° F.) lines of constant pressure (5 to 3000 lb. abs.) for the several constituents methane through heptane.

The light straight lines of Fig. 1 represent the equilibrium constant based on vapor pressures and Raoult's law. The latter is inaccurate at pressures above 300 lb. and at all times for constituents above the critical temperature of the pure compound.

The rise of the equilibrium constants to unity at a critical pressure of 5000 lb. for the particular mixture studied explains clearly the occurrence of constituents of high molecular weight in appreciable quantities in the vapor phase at high pressures. For instance, pentane is as volatile in the mixture studied at 3000 lb. and 120° F. as at 135 lb. and 120° F. The critical pressure is the pressure at which the vapor density equals the liquid density and only one phase exists.

This converging of the K's to a critical pressure injects another variable in addition to temperature and pressure on the value of K for a particular case. Fig. 1 also shows the equilibrium data of Sage and Lacey[12] on methane and propane in a binary system and indicates that the systems agree, but that equilibrium constants for mixtures having widely different critical pressures should not be expected to agree. Kay's[5] recent data on the ethane-heptane system is also shown on Fig. 1, giving good agreement of ethane K's but lower values for heptane than the extrapolated heptane values in crude oil primarily because Kay used n-heptane and the crude-oil heptanes contain a large proportion of lower boiling isomers. However, these binary systems and other data point to the probability that mixtures having intermediate critical pressures between the binary systems and the crude oil would have K's corresponding to curves converging to unity at the critical pressure for the particular system and possibly symmetrical with the systems shown.

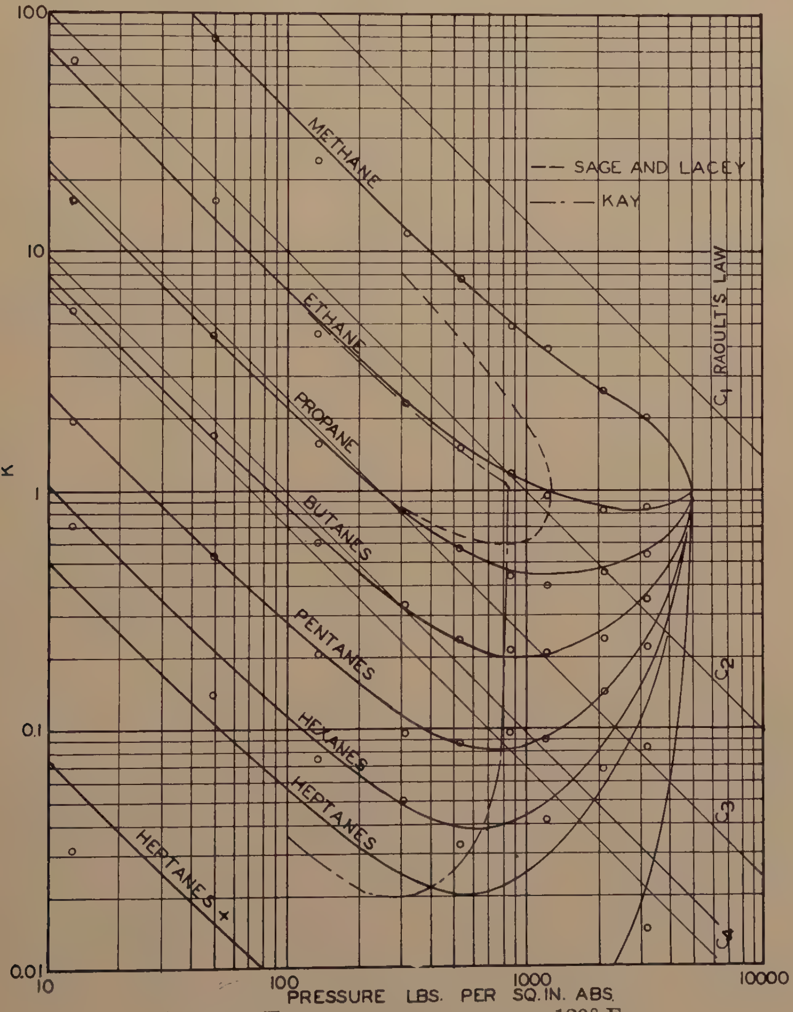


FIG. 1.—EQUILIBRIUM CONSTANTS AT 120° F.

Two sets of gas and liquid analyses of trap samples have been reported by Sage and Lacey[13,14] and trap samples properly taken are known to be representative of equilibrium conditions. The comparison of the K's with those of the charts for the crude oil-natural gas system are given by Table 1. The Kettleman Hills sample checks reasonably well and shows that although the critical of the mixture is likely to be less than that for crude oil, the convergence at 510 lb. is not significant. The ethane K of Kettleman Hills sample shows a subnormal value when K is plotted as log K versus temperature of atmospheric boiling point of constituent. The Conroe data differ considerably from those of the charts, possibly because of differences in chemical nature of the solvent or crude oil. However, discrepancies between individual sets of equilibria should not be used to form conclusions, as shown by irregularities of the data of Fig. 1 from the smoothed curves.

The recommended procedure for selecting equilibrium constants for a mixture is to use the crude-oil natural-gas data with adjustments for critical pressure of the mixture. It may also be necessary to adjust the constant for methane if the base of the crude oil is of a vastly different chemical constitution from that of the Oklahoma City crude. Cyclic compounds tend to raise the equilibrium constant for methane over similar paraffins.

TABLE 1.—*Comparison of Equilibrium Constants*

Constituent	Equilibrium Constants	
	Kettleman Hills Trap Samples at 510 Lb. Abs., 148° F.	Charts of Crude Oil Natural Gas, 510 Lb., 148° F.
Methane	7.9	8.0
Ethane	1.38	1.86
Propane	0.816	0.72
i-butane	0.34	
n-butane	0.251	0.305
i-pentane	0.148	
n-pentane	0.074	0.12

	Conroe Trap Samples 42.4 Lb. Abs., 68° F.	Charts 42.4 Lb. Abs., 68° F.
Methane	149	84
Ethane	16	10.6
Propane	3.15	2.8
Butanes	0.97	0.92

PHYSICAL PROPERTIES OF THE HYDROCARBONS

The calculation of the behavior of hydrocarbon mixtures from a molal analysis and the equilibrium constants results in the molal quantities present in each phase and the molal composition of the phases. This approach to the problem of understanding the properties of hydrocarbon mixtures is quite different from the direct measurement of the specific volume of a mixture, as done by Sage and Lacey,[13] or the differential vaporization of a high vapor-pressure liquid as initiated by Lindsly.[9] The later methods give accurate information for particular cases but fail to give a method of predicting the behavior of other mixtures. Also, the methods are not particularly concerned with the individual phases if two phases are present and do not follow the behavior of one phase if it is separated from the other. If the equilibrium constants and the physical properties of the volatile hydrocarbons were known when the constituents are present in all types of mixtures, it would be possible to compute the results of all the physical measurements made, in addition to the following of a particular phase and a knowledge of the constituents present. This ultimate goal is the objective of Sage and Lacey in their research project for the American Petroleum Institute.

At the present time reasonable estimates may be made of the volumetric properties of a hydrocarbon mixture under many conditions in either the liquid or gaseous phase. These computations require a knowledge of the partial volumes or apparent densities of the several constituents in either phase. The viscosity and specific-heat data primarily from Sage and Lacey are also approaching the stage that will permit the estimation of those properties from the analysis.

As an example of the computation of liquid densities, assume that a vaporization calculation resulted in the molal analysis of the Kettleman Hills trap sample of Sage and Lacey.[13] The molal analysis can be converted to the weight fractions reported by means of the molecular weights also reported. Table 2 shows such a conversion using the liquid densities at 60° F. to obtain the density of the mixture by assuming additive volumes. The change in density with temperature of the mixture at saturation pressure is best obtained by comparison with this variation for other saturated hydrocarbon liquids, as shown by Fig. 2. If the density of the trap sample at saturation pressure is assumed to follow a curve parallel to normal hexane, the values tabulated as calculated values in Table 2 are obtained. This check and the behavior of the saturated densities of Conroe depth sample,[14] natural gas in Dominguez crude,[16] methane in crude oil[15] and methane in Crystal oil,[11] as compared to pure hydrocarbons and the National Standard Petroleum oil tables, show that the saturated liquid density of a normal petroleum mixture at any temperatures existing in crude production may be estimated from the density at 60° F. and data such as shown in Fig. 2.

The choice of apparent densities at 60° F. of the more volatile hydrocarbons, especially methane, is not an easy task, as they may vary with saturation pressure and composition of the mixture. The value of the density for methane used in Table 2 was taken from earlier data of Lacey, Sage and Kircher[7] and the values of other pure hydrocarbons are the actual pure compounds. The check on the Kettleman Hills trap sample may be fortuitous but enough data are now available so that some correlation of the densities could be made.

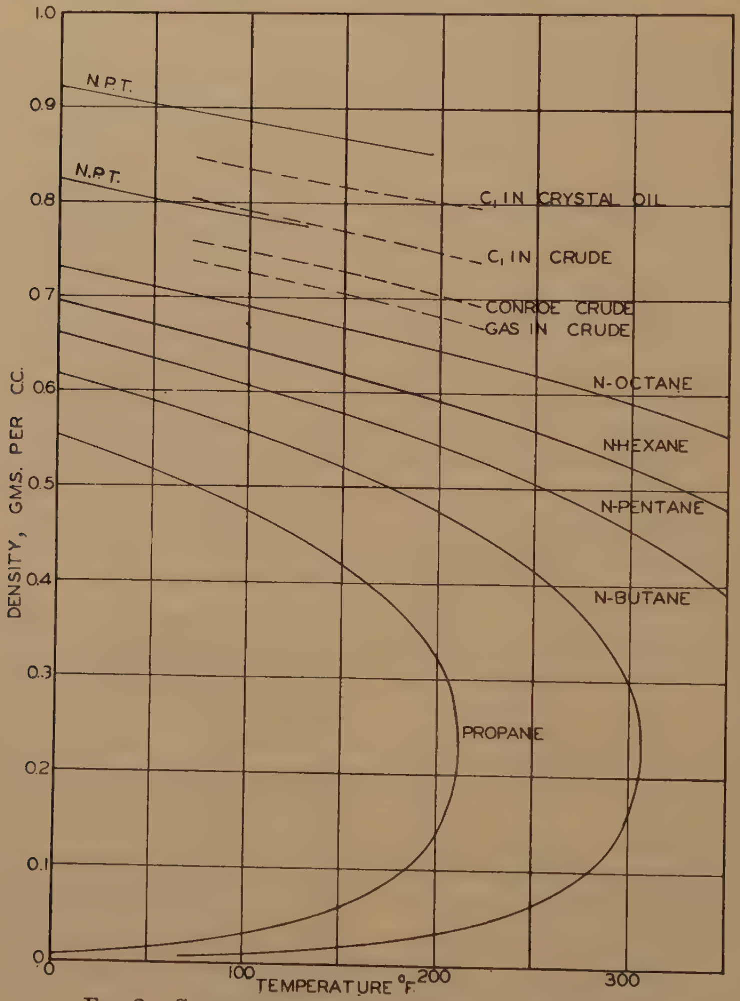


FIG. 2.—SATURATED DENSITIES OF THE HYDROCARBONS.

The densities of saturated and of superheated vapors may be approximated by finding the deviation of the mixture from ideal gas laws. The method presented by Kay[6] of calculating pseudocritical temperatures and pressures of gases by weighing the critical conditions of the pure compounds on a molal basis and using the deviation of the gas from ideal gases equal to methane (preferably) or ethylene at the same reduced conditions appears satisfactory. Also, the method[4] of using the deviation from ideal gases of a mixture of methane and propane of the same molecular weight as the gas and at the desired temperature and pressure is convenient. Both of these methods will permit the computation of the densities of the Kettleman Hills trap-gas sample within about 3 per cent of the experimental values over the entire range investigated from 70° to 220° F. and atmospheric to 3000 pounds.

TABLE 2.—*Computation of Liquid Densities of Kettleman Hills Trap Sample*[13]

Constituent	Weight Fraction	Specific Gravity at 60° F.	Cubic Centimeters per Gram
Methane	0.0193	0.33	0.0585
Ethane	0.0221	0.40	0.0552
Propane	0.0282	0.509	0.0554
i-butane	0.0156	0.564	0.0277
n-butane	0.0464	0.584	0.0795
i-pentane	0.0332	0.625	0.0531
n-pentane	0.0372	0.631	0.0590
Hexanes	0.0705	0.668	0.1056
152°–180° F. boil. pt	0.0740	0.7019	0.1054
180°–206°	0.0772	0.7223	0.1070
206°–218°	0.0796	0.7347	0.1087
218°–240°	0.0797	0.7466	0.1069
240°–259°	0.0809	0.7515	0.1077
259°–280°	0.0819	0.7607	0.1077
280°–301°	0.0831	0.7720	0.1078
301°–338°	0.0839	0.7788	0.1080
Residue	0.0873	0.8110	0.1076
	1.0000		1.4608 density = 0.6846

Temperature, Deg. F.	Calculated Density Grams per C.C.	Experimental Density Grams per C.C.
60	0.6846	
70	0.681	0.6831
100	0.666	0.6700
130	0.652	0.6543
160	0.637	0.6379
190	0.621	0.6211
220	0.604	0.6043

These two properties, gas and liquid densities, when known will permit the conversion of molal gas and liquid analyses and molal percentages vaporized into volume per cent vaporized or shrinkage on flashing. Also, pressure-volume curves may be computed and the densities of either gas or liquid streams may be calculated when desired.

The compressibility of liquids and viscosity of gases at low pressures may also be estimated from analyses by comparing with data on mixtures of comparable molecular weight and density. The viscosity of liquid mixtures can only be roughly estimated with present correlations but added data by Sage and Lacey should provide a reliable method for predicting this property.

STAGE SEPARATION

Stage separation is the equilibrium vaporization of natural gas from crude oil in two or more successive steps at different pressures. By separating a crude oil from the natural gas at a high pressure, the gas is available at a high pressure and the vaporization of the natural gasoline hydrocarbons are suppressed at the high pressure. The equilibrium constants enable the computation of the gas quantity and composition as well as the oil composition and gravity for any series of vaporizations from the analysis of the mixture vaporized. Computations will show the effect of using any system considered and often they will give results where experimental methods are impractical.

The commonest method of separating crude oil and natural gas is a single separator with the liquid going to a lease tank at atmospheric pressure. Table 3 gives the complete calculations of the separation of gas from an oil at 34.7 lb. abs. (20-lb. gauge) and 80° F. in a separator and subsequent flashing of the separator liquid at 14.7 lb. abs. and 80° F. The crude oil (column 1) used is a liquid from the equilibrium experiments[3] and is similar to saturated crude oil at 140° F. and 2175 lb. abs. The equilibrium constants (column 2) were taken from the data based on Oklahoma City crude oil. Columns 3 and 4 and columns 5 and 6 are solutions of equation 2[2] to find a calculated value of the mols vaporized equal to an assumed value.

$$\sum x = \frac{F}{v}\sum \frac{z}{K + \frac{1-v}{v}} = 1 \qquad [2]$$

in which x = mol fractions of constituents in separator liquid,
F = mols of feed mixture to a separator—taken as unity,
v = mols vaporized,
z = mol fractions of constituents in mixture going to separator,
K = equilibrium constant at separator temperature and pressure.

Equation 2 may be written:

$$\sum \frac{z}{K + \frac{1-v}{v}} = \frac{v}{F} = v \qquad [2a]$$

TABLE 3.—*Vaporization Calculation*

VAPORIZATION OF WELL FLUID AT 80° F., 34.7 LB. ABS.

Constituent	1 Mol Fraction (z) Well Fluid	2 K at 80° F., 34.7 Lb. Abs.	3 $K + 0.7$	4 $\frac{z}{K + 0.7}$
Methane	0.3398	105	105.7	0.0032
Ethane	0.0672	14.8	15.5	0.0043
Propane	0.0672	4.1	4.8	0.0140
Butanes	0.0515	1.35	2.05	0.0251
Pentanes	0.0414	0.395	1.095	0.0378
Hexanes	0.0414	0.148	0.848	0.0488
Heptanes and heavier	0.3915	0.010	0.71	0.5510
				0.6842
			v assumed	0.5882

Constituent	5 $K + 0.98$	6 $\frac{z}{K + 0.98}$	Mol Fractions 7 Liquid	 8 Vapor
Methane	106.	0.0032	0.0063^5	0.6675
Ethane	15.48	0.0043	0.0084^1	0.1245
Propane	5.08	0.0132	0.0261	0.1070
Butanes	2.33	0.0221	0.0437	0.0590
Pentanes	1.375	0.0301	0.0595	0.0235
Hexanes	1.128	0.0367	0.0726	0.0107
Heptanes and heavier	0.99	0.3958	0.7834	0.0078
		0.5054	1.0000	1.0000
	v assumed	0.5051		

VAPORIZATION OF SEPARATOR LIQUID AT 80° F., 14.7 LB. ABS.

Constituent	7 Liquid (z) Mol Fraction	9 K at 80° F., 14.7 Lb. Abs.	10 $K + 49$	11 $\frac{Z}{K + 49}$	12 $K + 75$	13 $\frac{z}{K + 75}$
Methane	0.0063	250	299	0.00002	325	0.000019^5
Ethane	0.0084	34	83	0.00010	109	0.000077
Propane	0.0261	9.3	58.3	0.00045	84.3	0.000309
Butanes	0.0437	3.1	52.1	0.00084	78.1	0.000559
Pentanes	0.0595	0.91	49.91	0.00119	75.91	0.000784
Hexanes	0.0726	0.34	49.34	0.00147	75.34	0.000964
Heptanes and heavier	0.7834	0.022	49.022	0.01598	75.022	0.010442
				0.02005		0.013155
			v assumed	0.02000	v assumed	0.013158

Constituent	Mol Fractions 14 Liquid	 15 Vapor	16 Corrected Vapor	17 Mol Wt.	18 Grams per Mol	19 Specific Gravity at 60° F.	20 Cubic Centimeters per Mol
Methane	0.00148	0.3710	0.364	16	0.02		
Ethane	0.00587	0.1995	0.196	30	0.18	0.40	0.44
Propane	0.02353	0.2188	0.215	44	1.03	0.509	2.03
Butanes	0.0425	0.1318	0.129	58	2.46	0.578	4.26
Pentanes	0.0596	0.0542	0.0541	72	4.29	0.628	6.83
Hexanes	0.0732	0.0249	0.0245	86	6.30	0.665	9.47
Heptanes and heavier	0.7938	0.0174	0.0171	225	178.6	0.855	209.00
	1.0000	1.0176	1.000		192.87		232.03

Mol per cent vaporized at 80° F., 34.7 lb. = 50.5; 14.7 lb. = 1.37.

$$\frac{192.9\text{ grams}}{232\text{ c.c.}} = 0.831\text{ density corresponding to }38.8°\text{ A.P.I. gravity or }291\text{ lb. per bbl. crude at }60°\text{ F.}$$

$$1\text{ mol well fluid}\begin{cases}0.505\text{ mol vapor}\\ 191\text{ cu. ft. at }60°\text{ F. }14.7\text{ lb.}\\ 0.495\text{ mol liquid}\begin{cases}0.00675\text{ mol vapor}\\ 2.55\text{ cu. ft. at }60°\text{ F. }14.7\text{ lb.}\\ 0.4883\text{ mol liquid}\end{cases}\end{cases}$$

To convert to barrels and cubic feet gas:
0.505 mol × 378 = 191 cu. ft. gas
0.4883 mol × 192.9 lb./291 = 0.323 bbl. crude per mol well-head fluid
1.0/0.321 = 3.09 mols well fluid per barrel crude oil.

$$3.09\text{ mols well fluid}\begin{cases}1.56\text{ mols vapor or }589\text{ cu. ft. gas}\\ 1.53\text{ mols liquid}\begin{cases}0.021\text{ mol gas} = 7.9\text{ cu. ft.}\\ 1.509\text{ mol liquid, }291\text{ lb. }1\text{ bbl. crude oil}\end{cases}\end{cases}$$

Calculated shrinkage (reservoir crude = 108 mol wt., 0.743 sp. gr. at 60° F.)
0.743 density at 60° F. = 0.718 at 140° F. from Fig. 2 = 251 lb. per bbl.
3.09 mols × $^{108}/_{251}$ = 1.33 bbl. reservoir crude
Shrinkage = 33.0 per cent based on residual crude.

A value of $\frac{1 - v}{v}$ is assumed and added to the K for each constituent. When the correct fraction vaporized has been chosen, the summation will equal the assumed v. It is always advisable to plot v assumed against the summation, or v calculated as small differences may still mean a rather large error in v. When the correct value of v has been found, division of summation of $\frac{z}{K + \frac{1 - v}{v}}$ by v gives $\sum x$ or liquid mol fraction (column 7). Multiplication of x by corresponding K will give mol fraction in vapor (column 8) by equation 1.

The vaporization occurring in the lease crude tank is computed by a similar computation using the separator liquid as the feed mixture z. This second stage of vaporization is slightly more difficult to solve than the former merely because the trial and error solution requires a closer check between v assumed and v calculated at low percentages vaporized. Fourth-place checks are not always perfect and a plot should be made with points on either side of the line of equality. Errors in v calculated will be reflected in the sum of the y's, or vapor mol fractions not equaling unity. A discrepancy of one or two mol per cent (column 15) at low percentages vaporized is satisfactory and the sum may be reduced or expanded to unity if desired (column 16). It is necessary to carry the methane and ethane of the liquid to three figures if the correct gas analysis is to be computed. Also, the fact that the K for heptanes plus is considered constant may give too high percentages of heptanes plus vaporized, especially at high vaporizations with high gas-oil ratios.

The calculation of molecular weight and density of resultant liquid is necessary to compute the cubic feet of gas per barrel of crude from the mol percentages vaporized; likewise, the shrinkage of the reservoir crude may be computed as shown in Table 3. In any series of separations, the liquid gravities and weight or liquid volume percentages vaporized may be computed. Fig. 3 shows the results in the usual units.

A so-called "two-stage" separation consisting of vaporizations at 315, 34.7 and 14.7 lb. abs. at 80° F. was computed for the same crude oil, and the results are given by Fig. 4. The calculation of the liquid gravities and shrinkages must be done with precision when making comparisons like those between Figs. 3 and 4, and slide-rule work, which was used in this case, should not be trusted to give gravity results to an accuracy of 0.1° A.P.I.

These calculations have been made to represent the vaporization of a reservoir crude sample when the well produces saturated liquid from a reservoir, as when new pools are flowing. If the crude analysis represents the reservoir liquid but the well is flowing at a higher gas-oil ratio than solution ratio, vaporization computations may be made upon a new mixture. As an example, consider the case of Fig. 3, with an experimental gas-oil ratio of 1500 cu. ft. per bbl., and assume that the crude analysis represents reservoir liquid at 2175 lb. abs. and 140° F. The gas in equilibrium with the reservoir crude is computed by the vapor-pressure calculation of the crude, or where

$$\Sigma xK = \Sigma y = 1 \qquad [3]$$

Table 4 shows the vapor-pressure calculation of the crude oil at 140° F., using close to the correct pressure and obtaining summation of

	MOL	GAS FRACTION
METHANE	.6675	.364
ETHANE	1245	.196
PROPANE	.1070	.215
BUTANES	.0590	.129
PENTANES	0235	.054
HEXANES	.0107	.0245
HEPTANES	0078	.0171

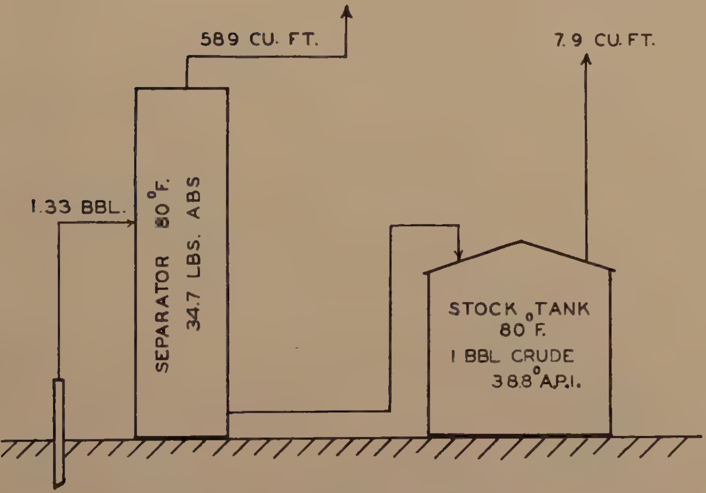


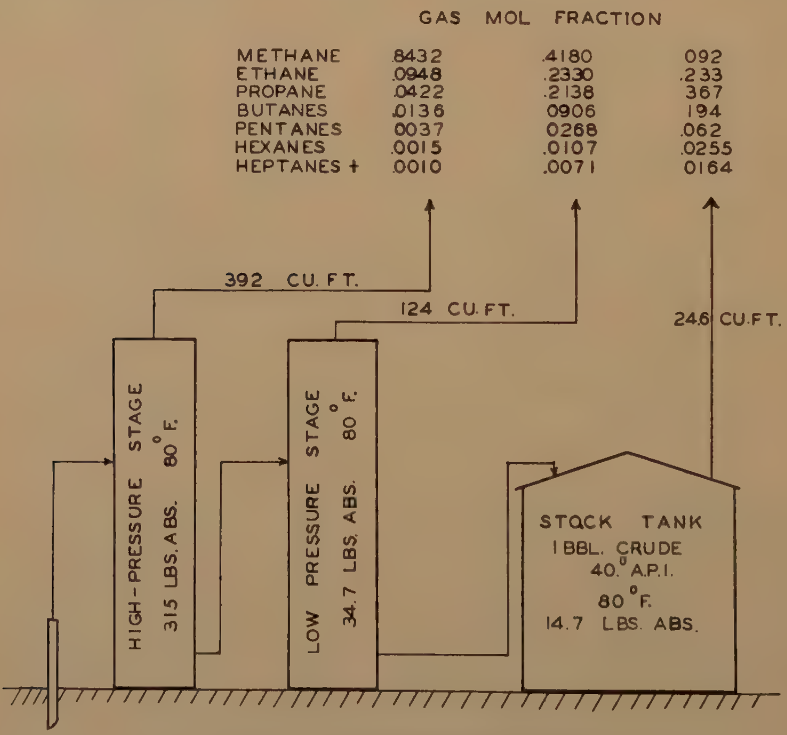
FIG. 3.—SINGLE-STAGE SEPARATION.

Kx to 0.999, or the gas composition in equilibrium with the liquid. The reservoir gas may not be exactly in equilibrium with crude but error is small in most cases. As the experimental gas-oil ratio is about 900 cu. ft. above the saturated gas-oil ratio, as computed, 800 cu. ft. of reservoir gas might be estimated as accompanying the saturated crude oil when allowing for the extra vaporization to occur for some constituents at the higher separator gas-oil ratio. The 800 cu. ft. convert to 2.12 mols of gas for 3.09 mols reservoir liquid for the 1 bbl. crude, so 0.68 mol of gas accompanies 1 mol of liquid. The addition of 0.68 mol gas (column 4) to 1 mol of reservoir liquid (column 1) gives the mixture comprising the well fluid, and when converted to mol fractions (column 6) is the feed analysis for

Table 4.—*Calculation of Well Fluid for Gas-oil Ratios above Solution Gas*

Constituent	1 Reservoir Liquid	2 K at 140° F., 2175 Lb. Abs.	3 $\left(\frac{Kx}{y}\right)$	4 0.68 Mol Fraction Reservoir Gas	5 Total Mols	6 New Mol Fraction Well Fluid
Methane	0.3398	2.57	0.8736	0.594	0.9338	0.5565
Ethane	0.0672	0.90	0.0605	0.0411	0.1083	0.0645
Propane	0.0672	0.52	0.0350	0.0238	0.0910	0.0541
Butanes	0.0515	0.295	0.0152	0.0103	0.0618	0.0368
Pentanes	0.0414	0.160	0.0066	0.0045	0.0459	0.0273
Hexanes	0.0414	0.100	0.0041	0.0028	0.0442	0.0263
Heptanes and heavier	0.3915	0.0102	0.0040	0.0027	0.3942	0.2345
			0.9990			

separator computations at the higher gas-oil ratio. A vaporization of this mixture was computed at 34.7 lb. abs. and the liquid again at 14.7 lb. abs., to give the results shown in Fig. 5.



	GAS MOL FRACTION		
METHANE	.8432	.4180	092
ETHANE	.0948	.2330	.233
PROPANE	.0422	.2138	367
BUTANES	.0136	0906	194
PENTANES	0037	0268	.062
HEXANES	.0015	.0107	.0255
HEPTANES +	.0010	.0071	0164

Fig. 4.—Two-stage separation.

The calculation of stage separations from crude analyses applicable to the system will give results as close as most experimental analyses of the fluids. This statement is based on the fact that liquid analyses are likely to be more accurate than gas analyses and the equilibrium-constant data show that any one analysis may be in error. Thus K from smoothed data may compute vaporizations more accurately than routine measurements are made and for future conditions for which experimental measurements are impractical. The gas analyses may be converted to natural gasoline contents by dividing the cubic feet of a constituent in a 1000 cu. ft. of gas by the cubic feet of vapor per gallon of condensate. The gas gravity is the ratio of its molecular weight to that of air.

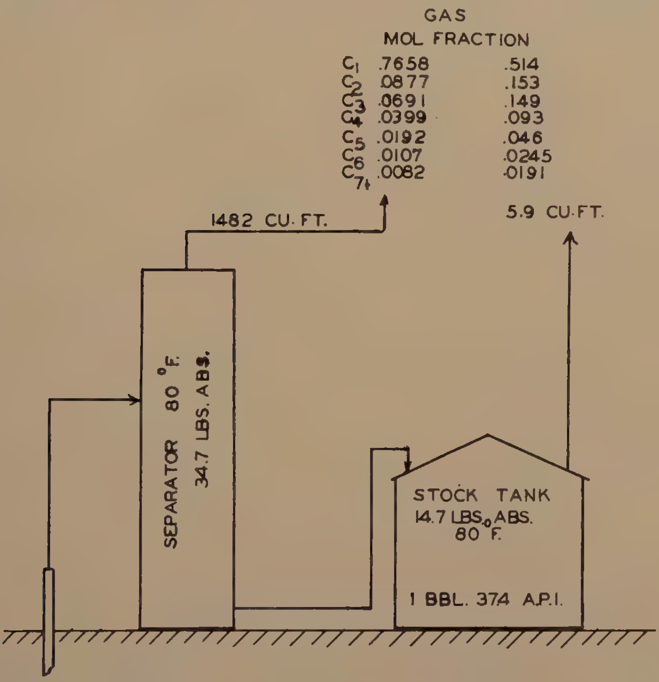


FIG. 5.—VAPORIZATION OF MIXTURE OF RESERVOIR LIQUID AND GAS.

A study of the problems of oil and gas separation will continually raise questions that can be solved by variations of the examples given. The crude-oil gravity or natural gasoline lost as a function of separator pressure may be computed. It may be shown that for low reservoir pressures saturated crude oil flashed at 60 lb. gauge in system of Fig. 3 may lose more natural gasoline in the stock-tank vapors than in the 60-lb. gas leaving the separator. The effect of gas-lift gas on oil gravity or gasoline content may also be computed for any gas-oil ratio.

PRESSURE-VOLUME CURVE OF OIL-GAS MIXTURE

Pressure-volume curves are often measured for reservoir fluids when studying such problems as fluid flow in tubing or oil and gas reserves. It may happen that such curves are desired when the oil to gas ratio has changed since the measurements were made or when no measurements have been made. In such cases a reservoir crude-oil analysis, the desired conditions of oil to gas ratio, temperature, and equilibrium constants will permit the computation of this curve.

The calculation of points on the *P-V* curve of the Conroe depth sample[14] was made as an example calculation. Unfortunately, the failure to publish the density of the hexane and heavier liquid of the analyzed sample makes the computation only a partial check with experimental results. The calculation of the bubble point or vapor pressure is usually made as one point on the curve. Table 5 shows this computation for the Conroe depth sample A at 160° F., with the result of 1875 ± 25 lb. abs. as compared to an experimental value of 1881 lb. abs.

The depth sample A was vaporized at 500 lb. abs. and 160° F. to obtain the volume of the mixture at these conditions. Column 6 is a successful trial for solving equation 2 and columns 7 and 8 give the composition of the phases present. The volume of the 0.279-mol vapor is computed by ideal gas laws and then corrected for the deviation. The method presented by Kay[6] of computing the pseudocritical temperature and pressure by weighting the critical values of the pure compounds (temperatures column 9, pressures column 10) according to the analysis is shown. The absolute temperature and absolute pressure divided by the pseudocritical temperature and pressure, respectively, give the reduced temperature (T_R) and reduced pressure (P_R). The gas was considered to have the same deviation from ideal gas laws as methane at the same T_R and P_R, or a value of $z = \frac{PV}{RT} = 0.952$. This correction when applied to the ideal gas volume gives 3.52 cu. ft. of gas per mol of mixture vaporized.

The calculation of the liquid volume per mol vaporized consists of finding the molecular weight and density of the liquid as shown by columns 13 to 16. The density of the liquid at 60° F. is converted to density at 160° F. by Fig. 2. The 0.729 mol of liquid becomes 2.17 cu. ft. liquid, or a total volume of 5.69 cu. ft. per pound-mol of mixture. As a partial check on the accuracy of the method, the ratio of calculated volume of one mol of the mixture at 500 lb. to the volume of one mol at 1875 lb. is compared with the experimental ratio. The check of 2.42 volumes computed to 2.39 volumes experimental is very good but the use of 0.83 as density of hexane and heavier as noted may have assisted in bringing the ratio closer together.

RESERVOIR ENGINEERING

There are many uses of equilibrium constants in every-day reservoir engineering problems if analyses of reservoir gases or liquids are available.

TABLE 5.—*Computation of Pressure-volume Curve*

VAPOR PRESSURE OF CONROE RESERVOIR CRUDE

Constituent	1 Mol Fraction Subsurface Sample	2 K at 160° F. 1875 Lb. Abs.	3 Mol-fraction Vapor Kx or y
Methane	0.3225	2.85	0.919
Ethane	0.0424	1.01	0.0427
Propane	0.0335	0.55	0.0184
Butanes	0.0256	0.31	0.0079
Pentanes	0.0218	0.167	0.0036
Hexanes and heavier	0.5542	0.015	0.0083
			0.9999

FLASH VAPORIZATION OF CONROE CRUDE AT 500 LB. ABS. AND 160° F.

Constituent	1 Mol Fraction Reservoir Crude	4 K at 160° F. 500 Lb. Abs.	5 $K + 2.6$	6 $\frac{z}{K + 2.6}$	Mol Fraction 7 Liquid	 8 Vapor
Methane	0.3225	8.3	10.9	0.0296	0.1065	0.884
Ethane	0.0424	2.01	4.61	0.0092^{0}	0.0331	0.067
Propane	0.0335	0.81	3.41	0.0098^{2}	0.0353	0.030
Butanes	0.0256	0.35	2.95	0.0086^{8}	0.0312	0.011
Pentanes	0.0218	0.14	2.74	0.0079^{6}	0.0286	0.004
Hexanes and heavier	0.5542	0.0048	2.605	0.2125	0.7653	0.004
		v assumed		0.2777	27.9 per cent vaporized	

VOLUMETRIC CALCULATIONS FOR VAPOR

Constituent	8 Mol F. Vapor	9 Critical Conditions Deg. Rankine	10 Lb. Abs.	11 Pseudo Temperature	12 Critical Pressure
Methane	0.884	345	673	305	595
Ethane	0.067	552	708	37	47.4
Propane	0.030	668	646	20	19.4
Butanes	0.011	750	536	8.7	5.9
Pentanes	0.004	840	484	3.3	1.9
Hexanes and heavier	0.004	915	435	3.6	1.7
				377.6° R	672.1 lb. abs.

160° F = 620° R

$\frac{620}{377.6} = 1.64T_R$

$500/672 = 0.745P_R$

$\frac{PV}{RT} = 0.952$ from CH_4 chart.

$$0.279 \times 378 \times \frac{620}{520} \times \frac{14.7}{500} \times 0.952 = 3.52 \text{ cu. ft. gas phase}$$

VOLUMETRIC COMPUTATIONS FOR LIQUID

Constituent	7 Mol Fraction Liquid	13 Mol Wt.	14 Grams per Mol	15 Density at 60° F.	16 Cubic Centimeters per Gram-mol
Methane	0.1065	16	1.7	0.35	4.8
Ethane	0.0331	30	1.0	0.40	2.3
Propane	0.0353	44	1.5	0.509	3.0
Butanes	0.0312	58	1.8	0.578	3.1
Pentanes	0.0286	72	2.1	0.628	3.3
Hexanes and heavier	0.7653	172	131.7	0.83[a]	158.8
			139.8 mol wt.		175.3

$$\text{Density } \frac{139.8}{175.3} = 0.796 \text{ at } 60° \text{ F. corresponding to } 0.755 \text{ at } 160° \text{ F.}$$

$$\frac{0.729 \times 139.8}{0.755 \times 62.4} = 2.17 \text{ cu. ft. liquid phase}$$

1 lb. mol at 1875 lb. = 106. lb. 106 × 0.02218 = 2.35 cu. ft. liquid
1 lb. mol at 500 lb. = 2.17 + 3.52 = 5.69 cu. ft.
Calculated volume at 500 lb. per 60° F. divided by volume at 160° F.
1875 lb. = 5.69 + 2.35 = 2.42
Experimental value = 2.39

[a] Assumed as corresponding to mol wt. and to computation of gravity of reservoir crude and equal to experimental.

A full understanding of equilibrium relations and the properties of the phases that may be estimated will prompt many applications of K.

The most evident relation is that if a reservoir liquid is obtained and analyzed in a new well of a pool, the analysis of the gas-cap gas if present can be computed for the reservoir temperature and pressure. Similarly, if a gas well is discovered and thought to be situated on the gas cap of an oil field, the dew point can be compared with the reservoir pressure and temperature, a calculation that gives the reservoir crude-oil composition if it is present. If a question should arise as to whether a crude oil from one well and gas from another well were in contact in the reservoir, an analysis of the two mixtures and comparison with equilibrium data would indicate the likelihood of present or previous contact. Such applications of equilibrium data assist geological information in showing the course of reservoirs or possible migrations of fluids.

The ability to calculate the quantity and composition of the reservoir phases during the life of the pool has advantages over the measurement of the combined volume. For instance, if there were segregation of the separating phases in a reservoir of unbalanced pressures, it would be possible to make rough estimates of the migration of either phase from the sand properties, physical properties of fluid, and pressure gradients. The viscosity and densities may be computed from the analyses of gases and liquids, or at least this will be possible shortly. This use of equilibrium constants and the physical properties of the hydrocarbons will also assist the engineer in solving problems of fluid flow into the well bore and in the flow string.

The study of the "productivity" of wells as initiated by Moore[10] and continued by Haider[1] may be aided by the use of equilibrium constants and the physical properties of the hydrocarbons. The "productivity index" is defined as the rate of production of crude oil in barrels per day for one pound drop in bottom-hole pressure, and has been shown to be a constant for wells producing entirely a liquid phase at the operating bottom-hole pressure. The vaporization of natural gas from crude oil at the bottom-hole pressure, or the accompanying of the crude by varying amounts of free gas, should be expected to vary the productivity index of a well for various conditions at the sand face. The radial permeability formula[18] may be used to show this effect of the gas volume accompanying the crude oil:

$$Q = \frac{cKt\Delta P}{\mu \log_e \frac{R_1}{R_2}} \tag{4}$$

in which Q = barrels of fluid per day,
k = permeability, millidarcy,
t = sand thickness, ft.,

ΔP = pressure differential from reservoir to well bore, lb. per sq. in.,
μ = viscosity of fluid at mean pressure, centipoises,
R_1 = distance from well to position where substantially reservoir pressure is maintained, ft.,
R_2 = radius of well bore,
C = constant.

To illustrate the use of vapor-liquid equilibria data as applied to productivity index, assume that the solid curve of Fig. 6 is the productivity curve of a well producing saturated Conroe reservoir crude with no free gas. The *PV* curve of Sage and Lacey[14] would permit the computation of the barrels of residual crude which were represented by the Q for various average pressures as shown in Table 6. Columns 1, 2 and 3 are assumed data, column 4 is the arithmetical mean pressure from sand face to reservoir body, column 5 shows values from reported *PV* curve, and column 8 gives the actual barrels of fluid flowing at mean pressure. If K, t, μ, R_1 and R_2 were known, the value of C could be computed, but this discussion is limited to variations in residual crude oil for a given value of Q at various conditions.

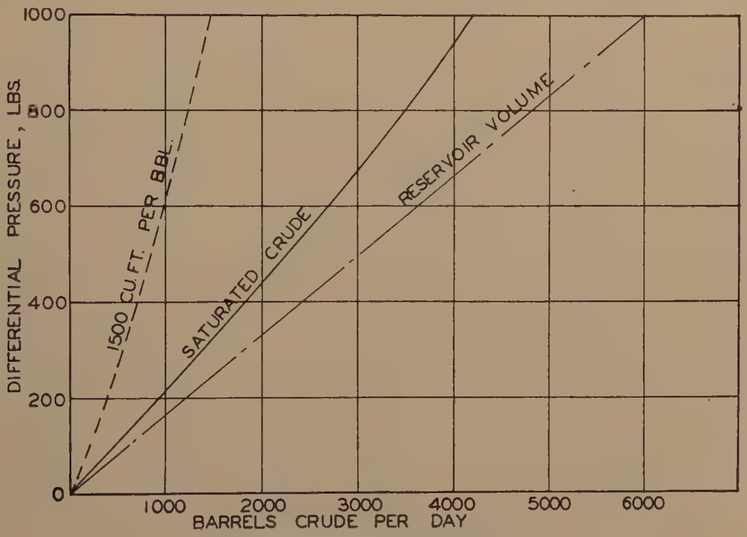


FIG. 6.—PRODUCTIVITY CURVES.

Let us further assume that the well in question changed from solution gas-oil ratio to 1500 cu. ft. per bbl. What is the productivity curve of the well at this condition? Theoretically the values of μ and R will change, which along with surface-energy effects would give a different relationship between Q and the differential bottom-hole pressure. However, let us neglect these factors for purposes of illustration and show the volumetric effect of the gas-oil ratio on the productivity curve. The 1500 cu. ft. of gas is divided into 443 cu. ft. of solution gas and 1057 cu. ft. of free gas at the shut-in reservoir pressure. The free gas may be added to the reservoir crude oil as shown in Table 4 and the *PV* curve computed for this new mixture at 160° F., the assumed reservoir temperature. These volumes of one barrel of residual crude with accompanying gas at the mean pressures are given by column 7, Table 6. The conversion of the reservoir fluid volume to residual crude is shown in column 8, values that are plotted on Fig. 6 as the new productivity curve.

TABLE 6.—*Productivity Computations*

Assumed Data			Saturated Crude Oil		
1 Bbl. Crude per Day	2 Bottom-hole Pressure, Lb. Abs.	3 ΔP, Lb. per Sq. In.	4 Mean Pressure, Lb. Abs.	5 Volume of One Barrel Residual Crude at P_m, Bbl.	6 Q for Eq. 4
0	1875	0	1875	1.23	0
945	1675	200	1775	1.27	1200
1850	1475	400	1675	1.30	2400
2690	1275	600	1575	1.34	3600
3480	1075	800	1475	1.38	4800
4200	875	1000	1375	1.43	6000

CONDITIONS OF 1500 CU. FT. PER BBL. RESIDUAL CRUDE

6 Q of Eq. 4	4 Mean Pressure, Lb. Abs.	7 Volume of One Barrel Residual Oil + Gas at Mean Pressure	8 Residual Crude Corresponding to Q
0	1875		
1200	1775	3.25	370
2400	1675	3.45	696
3600	1575	3.62	995
4800	1475	3.85	1250
6000	1375	4.10	1464

Although other factors than volume have been neglected, this computation would allow the checking to see whether other factors will change the productivities under various conditions. Also, this illustration might have taken the direction of computing the values of Q, or reservoir fluid, for an experimental productivity curve with gas-oil ratio changing with the flow rate. These computations on actual productivity curves will eliminate the volumetric factor and should bring the results closer to constant values for productivity index based on reservoir fluid rather than residual crude oil.

CONCLUSION

Equilibria data for the volatile constituents in crude oil-natural gas systems have been reviewed and the auxiliary physical properties of the hydrocarbons have been discussed. Methods of computing equilibrium vaporizations of mixtures of crude oil and natural gas have been illustrated. Examples of the many uses of this information in petroleum engineering were given; stage separation, *PV* curves, and reservoir engineering problems.

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DISCUSSION

(*T. V. Moore presiding*)

S. E. BUCKLEY,* Houston, Tex. (written discussion).—Rapid strides are being made in the field of calculating the behavior of the lighter hydrocarbons under the various conditions in which they occur underground and in the changes of phase which they undergo during and after production. The excellent experimental work being done by Lacey, Sage, and coworkers under the auspices of the American Petroleum Institute is adding substantially to the store of knowledge concerning the behavior of both simple and complex mixtures. This paper by Dr. Katz is very timely in that it shows the practical uses to which the accumulating mass of data may be put. The possibility pointed out by Dr. Katz of using a knowledge of the composition of the fluids entering a well to calculate the compositions of the gas and of the oil separated at various stages is not only intriguing but is already proving extremely practical. The necessary data are secured from examination of subsurface samples of the reservoir fluids. The technique of calculation outlined by Dr. Katz permits the accurate and complete determination of the effects of various production practices and is a valuable tool for use in studying both the physical and economic sides of many field operations.

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Calculation of Equilibria in Hydrocarbon Mixtures

By Stuart E. Buckley*

(Oklahoma City Meeting, October, 1937)

The application of hydrocarbon equilibrium data to various problems encountered in refining and in natural gasoline recovery is an old and well established practice. Both generalized data and data on specific hydrocarbon systems have been made available by a number of investigators. More recently such data have been applied to the relations governing the separation of oil and gas both in the reservoir and at the surface. Most of the applications to production problems, however, have been based upon examinations of surface samples of oil and gas. This paper describes a technique that has been used satisfactorily in a number of cases to calculate directly from the hydrocarbon analysis of and auxiliary laboratory data on a subsurface sample of the reservoir fluid the behavior of the oil and gas during the various stages of separation at the surface incident to production.

TYPES OF INFORMATION CALCULATED

The system of calculations is not designed to supplant field data, but rather to correlate with them laboratory data obtained under controlled conditions in order to obtain a more complete and exact picture than usually is possible through the use of field data alone. The chief advantage of the calculations is the possibility of their use at a minimum of both time and expense to determine completely the effect of any possible operating technique upon each of the following: (1) The gas-oil ratio resulting from liberation of the dissolved gas; (2) the composition and gasoline content of the liberated gas; (3) the composition and gravity of the residual oil; (4) the amount and composition of the gas liberated upon flashing the oil from the separator to the stock tank; (5) the shrinkage of the oil in passing from the reservoir to the stock tank.

This information is frequently essential to the correct determination of the advisability of installing a natural gasoline plant, to design such a plant to take care of seasonal production, and to determine the optimum separator pressures to carry in various parts of a field.

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Experimental Data Required

Carefully selected laboratory data, all of which are secured from a subsurface sample of the reservoir fluids, are necessary for the correct application of the calculations to any specific field. The following information is usually obtained: (1) Hydrocarbon analysis of the saturated reservoir fluid through the hexanes; (2) fractional distillation of the residual oil through nonane; (3) the molecular weights and specific gravities of the hexane-free material, the nonane-free material, and the intermediate fractions; (4) hydrocarbon analyses of the gases liberated from the oil by flash or equilibrium vaporization at atmospheric pressure at a minimum of two elevated temperatures; (5) the respective volumes and gravities of the gas and the oil obtained by flashing the reservoir fluid at room temperature at several controlled pressures; (6) the density, thermal expansion, and compressibility of the saturated reservoir fluid.

One subsurface sample usually suffices for all of the determinations, although two samples are usually used to obtain check results.

Equilibrium between Gas and Oil

The fundamental assumption involved in the calculations is that, owing to intimate mixing in the flow string, the oil and associated gas are at all times in instantaneous equilibrium at the existing temperature and pressure. Thus, the temperature and pressure at the final point of separation determine the compositions of the separated streams. While it has been observed that under some conditions equilibrium is not completely attained in the separator, sufficient data have been obtained to indicate that equilibrium is closely enough approached for the calculations to have wide application.

The equations that serve as the basis for the calculation of the qualities and relative quantities of gas and oil resulting from equilibrium vaporization of a mixture of known composition may be derived in the following manner:

Let X_o = total mols of original material.
L = total mols of liquid at equilibrium.
V = total mols of gas at equilibrium.
x = mol fraction of any component in the liquid.
y = mol fraction of any component in the gas.
$K = y/x$ = equilibrium constant, unique for each component, function of temperature and pressure.

By a material balance on the whole

$$X_o = L + V \tag{1}$$

A material balance on any particular component n gives

$$x_{on}X_o = x_nL + y_nV \tag{2}$$

where the subscript o is used to denote the original conditions. Substituting $x = y/K$ in equation 2,

$$x_{on}X_o = y_nL/K + y_nV \tag{3}$$

$$y_n = \frac{Kx_oX_o}{KV + L} \tag{4}$$

Substituting $L = X_o - V$ from equation 1,

$$y_n = \frac{Kx_oX_o}{KV + X_o - V} \tag{5}$$

It is convenient to base the calculations on one mol of original material, in which case $X_o = 1$ and equation 5 reduces to

$$y_n = \frac{Kx_o}{V(K - 1) + 1} \tag{6}$$

Since $x = y/K$

$$x_n = \frac{x_o}{V(K - 1) + 1} \tag{7}$$

Various algebraic transformations of equations 6 and 7 are used in the calculation of flash vaporization, but for many applications to production problems the forms shown are convenient because their solutions yield directly the analyses of the liberated gas and the residual oil.

The calculation of the flash vaporization is made by trial and error, a value of V being assumed and either equation 6 or equation 7 solved for each component of the mixture. The correct value of V is that at which the sum of the mol fractions of the components in either phase is equal to unity.

Equilibrium Constants

The accuracy of the equilibrium constants used in the equations governs to a large extent the accuracy of the calculated results. It is well known that the extremely varied hydrocarbon mixtures of which crude oil is composed do not form ideal solutions. Data, however, are rapidly being made available by which it is possible to make suitable corrections to care for most deviations found at normal pressures. The "ideal" equilibrium constants published by Katz and Brown[1] have been found very useful as a basis to which to apply the corrections for the hydrocarbons heavier than methane. Often these constants yield satisfactory results without correction.

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[1] D. L. Katz and G. G. Brown: Vapor Pressure and Vaporization of Petroleum Fractions. *Ind. Eng. Chem.* (1933) **25**, 1373.

No universally reliable set of equilibrium constants has ever been published for methane, primarily because of the differences in its behavior in different solvents. The author has compiled a set of average values from data obtained on a number of subsurface samples of reservoir fluids of different origins, however, which apply fairly well to most oils with gravities between 30° and 45° A.P.I. at pressures up to 3000 lb. per sq. in. Fig. 1 is a chart of these constants, covering the temperature range encountered in normal production practice. The nature of the data from which they were derived is such that they are most exact at pressures from 500 to 3000 lb. per sq. in. It is interesting that recently published data by Katz and Hachmuth[2] on the equilibrium between gas and a 38.4° A.P.I. oil yielded equilibrium constants for methane in substantial agreement with those of the author, especially at high pressure.

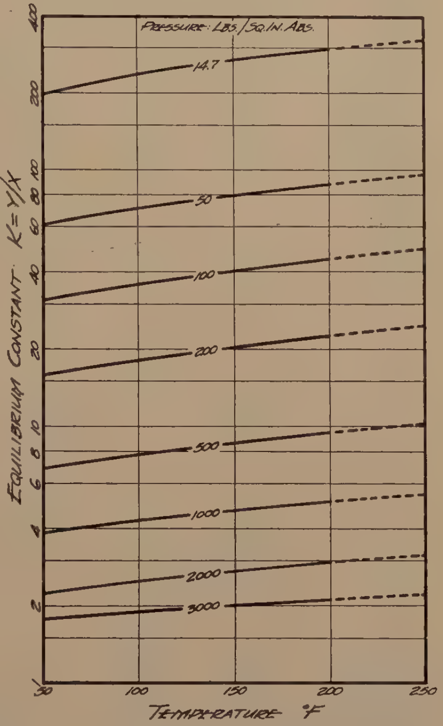

FIG. 1.—EQUILIBRIUM CONSTANTS FOR METHANE.

SAMPLE CALCULATIONS

Tables 1 to 4 illustrate the details of the calculations for a typical Gulf Coast field. Table 1 contains the analytical data on the saturated reservoir fluid. Table 2 shows the conversion of the analysis of the original material from a weight to a mol basis. The determination of the number of mols contained in a barrel of the original saturated fluid at the reservoir temperature and pressure is also indicated.

Table 3 contains the calculations of the flash vaporization of the original fluid at a separator pressure of 0 lb. per sq. in. gauge and a temperature of 130° F. The author's equilibrium constants were used for methane, while the constants for the components ethane through heptane were taken from large-scale charts obtained from Dr. G. G. Brown, of Ann Arbor, Mich. The constants for the octanes and nonanes were calculated from their vapor pressures by the application of a positive correction to make them comparable to Brown's constants for heptane.

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[2] D. L. Katz and K. H. Hachmuth: Vaporization Equilibrium Constants in a Crude Oil-Natural Gas System. *Ind. Eng. Chem.* (1937) **29**, 1072.

TABLE 1.—*Analytical Data on Saturated Reservoir Fluid*

Component		Wt. Per Cent in Original Saturated Fluid	Specific Gravity at 60° F.	Molecular Weight
Methane	C_1	7.45		
Ethane	C_2	1.22		
Propane	C_3	1.06		
Iso-butane	i-C_4	0.91		
N-butane	n-C_4	0.73		
Iso-pentane	i-C_5	0.50		
N-pentane	n-C_5	0.79		
Hexanes	C_6	2.11		
Heptanes	C_7	3.27	0.7255	100
Octanes	C_8	3.21	0.7425	114
Nonanes	C_9	4.21	0.7635	128
Heavier	C_{10+}	74.54	0.8342	203
Total		100.00		

TABLE 2.—*Conversion of Analysis of Original Material from Weight to Mol Basis*

Component	Wt. Per Cent	Molecular Weight	Mols per 100 Lb.	Mol Fraction
Methane	7.45	16.03	0.4645	0.4380
Ethane	1.22	30.05	0.0406	0.0382
Propane	1.06	44.06	0.0241	0.0227
Iso-butane	0.91	58.08	0.0157	0.0148
N-butane	0.73	58.08	0.0126	0.0119
Iso-pentane	0.50	72.09	0.0069	0.0065
N-pentane	0.79	72.09	0.0110	0.0104
Hexanes	2.11	86.11	0.0245	0.0231
Heptanes	3.27	100.	0.0326	0.0307
Octanes	3.21	114.	0.0281	0.0265
Nonanes	4.21	128.	0.0328	0.0309
Heavier	74.54	203.	0.3672	0.3463
Total	100.00		1.0606	1.0000

MOLS PER BARREL OF ORIGINAL OIL

From *P-V-T* data: 1 bbl. original saturated oil at reservoir temperature and pressure weighs 232.2 lb.

$$\text{Therefore, 1 bbl. original oil} = \frac{232.2(1.0606)}{100} = 2.463 \text{ mols}$$

TABLE 3.—*Calculation of Flash Vaporization at 130° F. and 0 Lb. per Sq. In. Gauge*

Component	Mol Fraction in Original Oil, x_o	Equilibrium Constant, $K = y/x$	Kx_o	$K - 1$	$V(K - 1)$ at $V = 0.551$	Mol Fraction in Gas: $y_n = \frac{Kx_o}{V(K-1)+1}$	Mol Fraction in Oil: $x_n = \frac{x_o}{V(K-1)+1}$	Gal. at 60° F. per Mol Oil	Lb. per Mol Oil
Methane..................	0.4380	256.	112.2	255.	140.6	0.7925	0.0031	0.022	0.050
Ethane..................	0.0382	28.	1.07	27.	14.88	0.0673	0.0024	0.022	0.072
Propane..................	0.0227	13.	0.2953	12.	6.61	0.0387	0.0030	0.031	0.132
Iso-butane..............	0.0148	6.7	0.0991	5.7	3.14	0.0239	0.0036	0.044	0.209
N-butane................	0.0119	4.9	0.0584	3.9	2.149	0.0185	0.0038	0.045	0.221
Iso-pentane..............	0.0065	2.1	0.01364	1.1	0.606	0.0085	0.0041	0.057	0.296
N-pentane...............	0.0104	1.66	0.01728	0.66	0.364	0.0126	0.0076	0.104	0.548
Hexanes.................	0.0231	0.63	0.01457	−0.37	−0.204	0.0183	0.0290	0.451	2.497
Heptanes................	0.0307	0.245	0.00753	−0.755	−0.416	0.0129	0.0525	0.870	5.257
Octanes.................	0.0265	0.087	0.002332	−0.913	−0.503	0.0047	0.0533	0.984	6.084
Nonanes.................	0.0309	0.032	0.000989	−0.968	−0.533	0.0021	0.0661	1.333	8.471
Heavier..................	0.3463	0.0		−1.0	−0.551		0.7715	22.543	156.615
Total..................	1.0000					1.0000	1.0000	26.506	180.416

$$\text{Gas-oil ratio} = \frac{0.551}{0.449}\,\Big|\,\overset{\text{mols/mol residual oil}}{379}\,\Big|\,\overset{\text{cu. ft./mol residual oil}}{\frac{42}{26.506}}$$

= 737 cu. ft. measured at 60° F., 14.7 lb. per sq. in. abs. per barrel residual oil corrected to 60° F.

$$\text{Gravity of residual oil} = \frac{180.416}{26.506} = 6.807 \text{ lb. per gal.} = 41.6° \text{ A.P.I. at } 60° \text{ F.}$$

$$V_R/V_S = \frac{26.506}{42}\,\Big|\,\overset{\text{bbl./mol residual oil}}{0.449}\,\Big|\,\overset{\text{bbl./mol original oil}}{2.463}$$

= 0.698 bbl. residual oil corrected to 60° F. per barrel original saturated oil measured at reservoir temperature and pressure.

It was found that a value of $V = 0.551$ satisfied the requirements that $\Sigma y_n = 1$ or $\Sigma x_n = 1$, giving correct solutions of the equilibrium equations. The analysis of the liberated gas is determined as mol fractions, but since, for a gas, volume and mol percentages are identical, a shift of the decimal point converts the analysis to per cent by volume.

The weight and volume of a mol of the residual oil were obtained by multiplying the mol fraction of each component by its molecular weight and by its molal volume, respectively. The molal volumes of the heptanes and heavier materials were obtained from their determined molecular weights and specific gravities, while the molal volumes of the other constituents, except methane, were taken from published data. The molal volume of methane in a particular oil is a characteristic of the oil and must be determined for each case. For the oil under consideration, it was determined by difference in the following manner: The total volume of a unit weight of the original oil if it were possible to maintain it in the saturated state at 0 lb. per sq. in. gauge and 60° F. was determined by extrapolation of the laboratory data on the pressure-volume-temperature relations of the saturated fluid. The volume of the known weight of the dissolved methane was then obtained from the difference between the volume of the total fluid and the calculated volume of the other components. It was assumed for the subsequent calculations that the factor so derived for the dissolved volume of the methane would not be affected by changes produced in the oil by the release of gas from solution.

TABLE 4.—*Comparison of Calculated and Determined Analyses of Gas Liberated at* 0 *Lb. per Sq. In. Gauge at* 130° *F.*

Component	Per Cent by Volume	
	Calculated	Determined
Methane	79.25	79.59
Ethane	6.73	6.60
Propane	3.87	3.89
Butanes	4.24	4.04
Pentanes	2.11	2.11
Hexanes	1.83	1.77
Heptanes plus	1.97	2.00
Total	100.00	100.00

The calculations of the gas-oil ratio and the gravity of the residual oil, shown also in Table 3, are self-explanatory. The "shrinkage" factor of the oil, expressed as barrels of residual oil corrected to 60° F. per barrel of original saturated fluid measured at the reservoir temperature and pressure, was obtained by multiplying the calculated volume of a mol of the residual oil by the number of mols of residual oil obtained from one barrel of the original saturated fluid.

Before proceeding further with the calculations, it is usual to compare the calculated analysis of the gas with that of the gas flashed from the original fluid in the laboratory at the same temperature and pressure. This comparison is made for the purpose of checking the equilibrium constants used and to determine the degree to which the particular mixture deviates from the ideal. The comparison is made at high temperature to take advantage of the greater concentration of heavier

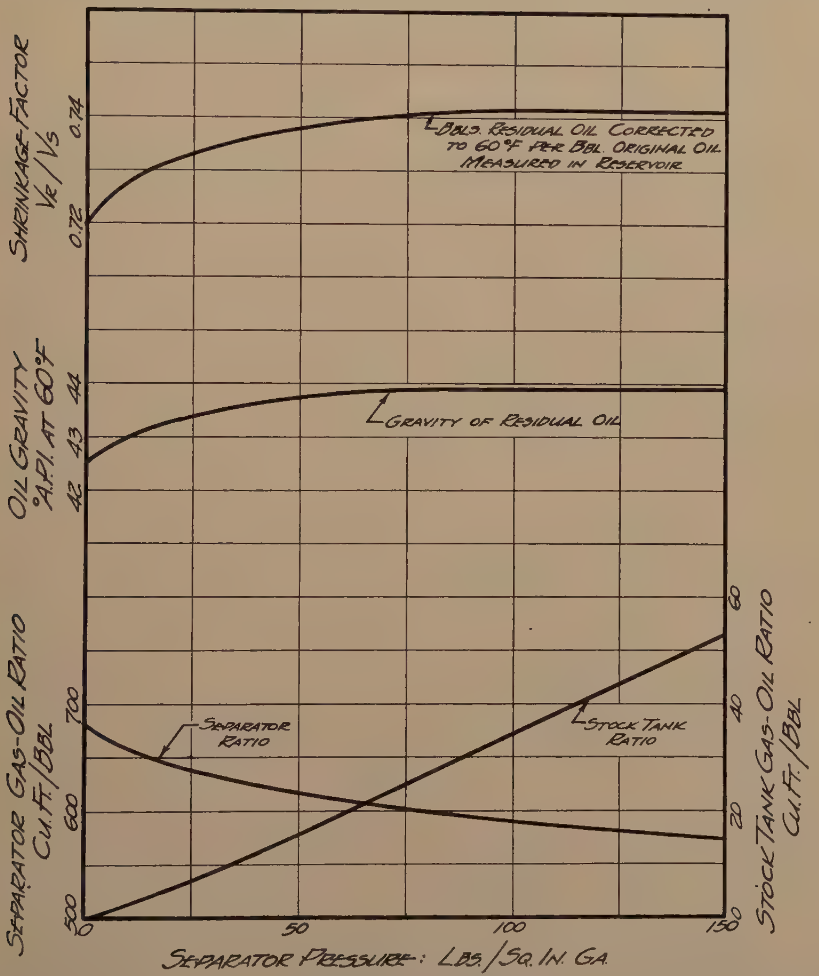

FIG. 2.—EFFECT OF SEPARATOR PRESSURE ON PROPERTIES AND RELATIVE AMOUNTS OF OIL AND GAS AT 70° F.

hydrocarbons present in the gas. This greater concentration permits a more accurate hydrocarbon analysis and tends to magnify any absolute discrepancies between the calculated and the determined results. When the results check at high temperatures, it is possible to proceed with the assurance that the calculated analyses at normal temperatures and moderate pressures will be satisfactory.

Table 4 contains a comparison of the calculated analysis of the gas liberated at 130° F. with that actually obtained in the laboratory. The agreement in this particular case was such that no correction to the equilibrium constants was necessary.

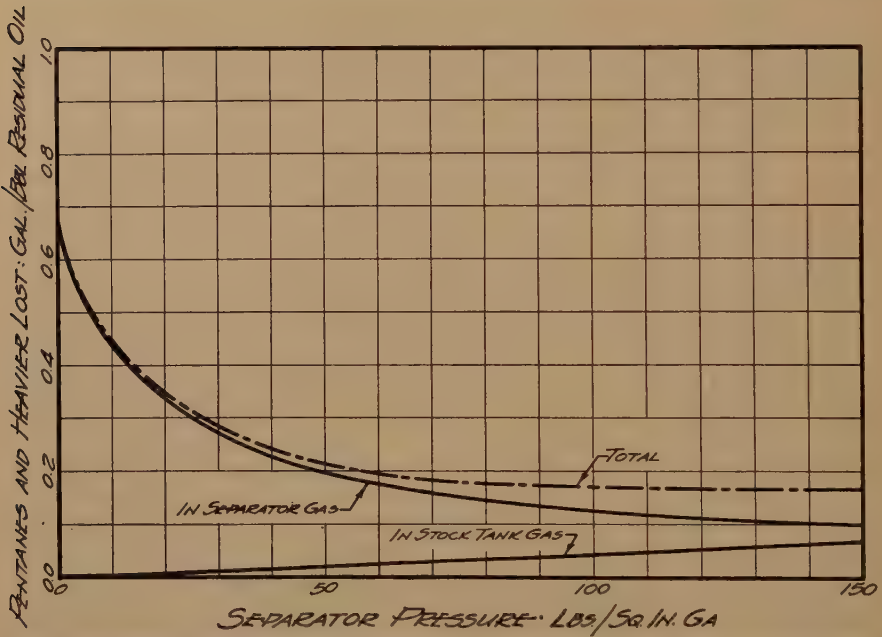

Fig. 3.—Effect of separator pressure on losses of pentanes and heavier at 70° F.

Two complete sets of calculations are necessary for the condition of a separator operating at a pressure greater than atmospheric. The first calculation is similar to the one in Table 3, involving merely the calculation of the flash vaporization of the original fluid at the conditions existing in the separator. This calculation yields the compositions of the separator oil and gas. The separator oil, however, undergoes a second vaporization upon being released to atmospheric pressure in the stock tank, and the composition and relative amount of the final stock tank oil is dependent upon the conditions at each of the liberations. The calculation of the second vaporization is similar to that of the first with the exception that the separator oil rather than the reservoir fluid is the material being flashed.

The effects of increasing gas-oil ratio due to the production of excess free gas from the reservoir, or the effects of gas lift upon the qualities of the resultant oil and gas, may be determined by similar calculations. In such cases, it is necessary to determine the composition of the excess gas. The fluid to be flashed consists of the mixture of oil and associated gas and has a composition determined by the relative quantities of original oil and gas present.

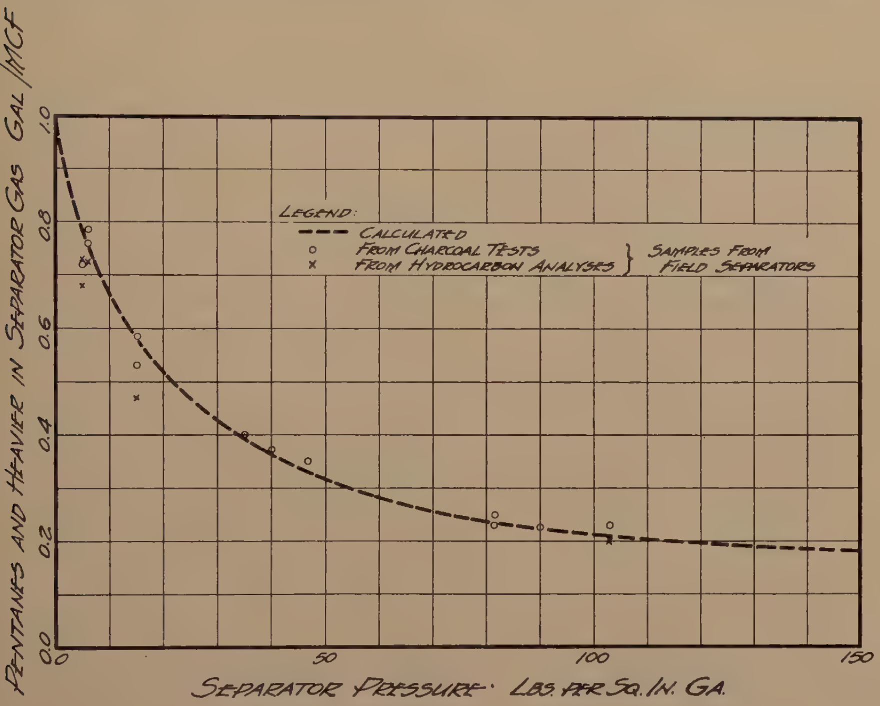

FIG. 4.—EFFECT OF SEPARATOR PRESSURE ON GASOLINE CONTENT OF SEPARATOR GAS.

CORRELATION OF CALCULATED RESULTS

It is customary to calculate all of the desired information at three temperatures, corresponding to the seasonal extremes and the yearly average for the particular region involved, and at a series of separator pressures from atmospheric to 150 lb. per sq. in. gauge. The data are then plotted to give a composite picture of the effect of production technique in the particular field. Figs. 2, 3 and 4 illustrate the effect of separator pressure on items of particular significance. Fig. 2 shows the effect of separator pressure at 70° F. on the separator and stock tank gas-oil ratios, the gravity of the residual oil, and the barrels of stock tank oil obtained per barrel of original saturated oil measured in the reservoir. Fig. 3 illustrates the effect of separator pressure on the losses of pentanes and heavier hydrocarbons per barrel of residual oil, both in the separator and in the stock tank gases. Fig. 4 shows the effect of separator pressure at 70° F. on the gasoline content (pentanes and heavier) of the separator gas. Data obtained by hydrocarbon analyses and by charcoal tests on separator-gas samples from a number of wells in the field are included for comparison. The agreement between the calculated values and the field data in this instance was excellent.

Behavior of Contents of High-pressure Reservoirs

By Eugene A. Stephenson,* Member A.I.M.E.

(Oklahoma City Meeting, October, 1937)

In most instances the fluids produced from underground reservoirs have been described as they appear at the surface, and usually it has not been necessary to distinguish between surface and reservoir phases. More recently it has become imperative to recognize the fact that changes in phase may occur between the reservoir and the receiving unit.

The simple terminology of "wet" and "dry" gases and "crude petroleum oil" served our needs fairly well in the shallow, low-temperature and low-pressure fields. It has been left to the legislatures, regulatory commissions, and courts to decide whether a field is or was a gas field, an oil field, or both. This they have done by direct definition and also by implication. For example, in Texas:[1]

> (*d*) The term "gas well" is any well (*a*) which produces natural gas not associated or blended with crude petroleum oil at the time of production, or (*b*) which produces more than one hundred thousand (100,000) cubic feet of natural gas to each barrel of crude petroleum oil from the same producing horizon, or (*c*) which produces natural gas from a formation or producing horizon productive of gas only encountered in a well bore through which crude petroleum oil is also produced through the inside of another string of casing.
>
> (*e*) The term "oil well" is any well which produces one (1) barrel or more of crude petroleum oil to each one hundred thousand (100,000) cubic feet of natural gas.

In the state of Louisiana, the same general result is achieved largely by the following paragraph:[2]

> Wells producing both oil and gas shall not waste or blow into the air an amount of gas of more value at three cents per thousand cubic feet, than the market value of the oil recovered. The Commissioner of Conservation shall allow a reasonable time to determine the status of any well.

This means that for wells making both oil and gas, if n represents the price of oil in dollars, and x the allowable gas waste expressed in M cu. ft. per day,

$$x = \frac{n}{0.03}$$

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* Professor of Petroleum Engineering, University of Kansas, Lawrence, Kansas.

[1] References are at the end of the paper.

For example, if oil is selling at $0.90 per barrel, 0.90/0.03 = 30, which is the allowable M cu. ft. per barrel that may be blown to the air daily from the particular well under consideration.

A much more precise concept of the distinction between an oil well and a gas well was given by the Federal Judges for the Western District of Texas (Austin Division) in the case of the Clymore Production Co. vs. E. O. Thompson et al. (The Texas Railroad Commission),[3] in 1936. The plaintiff—Clymore—owned a few wells which it classified as oil wells, although these had gas-oil ratios of 86,500 cu. ft. per barrel. Gas at the rate of 45 million cubic feet per day was being blown into the air in order to produce about 500 bbl. of the "crude oil." The waste of the gas produced with such oil was depleting a valuable reservoir, which was more or less essential to the supply of a large natural gas system, therefore the Commission had ordered the wells shut in, and had also refused to issue tenders for the sale of the "crude oil." Litigation developed when Clymore endeavored to restrain the Commission from enforcing its orders.

In preparation for the trial, it was recognized that the technical data would need to be presented in the simplest possible form, and that some field experiments should be conducted. The wells are approximately 4900 ft. deep, had measured bottom-hole temperatures of 151° F., and calculated bottom-hole pressures of 1950 lb. per sq. in. No actual bottom-hole pressure measurements were available, but the gravity of the gas and the depth of the wells were used in computing the bottom-hole pressure. A series of 4-hr. well tests was made, extending over a period of several days, and the following data were acquired: well-head pressure on both tubing and casing, choke sizes, temperature and pressure on both sides of the choke, pressures and temperatures at the separator, amount of gas produced, barrels of "oil" produced, quantity of water condensed (produced with the gas and "oil"), as well as subsequent analyses of the gas, "oil" and water. Further tests were made with a high-pressure separator installed on the upstream side of the chokes, operated with pressures approximately equal to the tubing-head pressures. The usual low-pressure separator continued to function on the downstream side of the choke.

As a result of these experiments, it was found that the "oil" was in reality a "condensate," the formation of which appeared to be induced by the fall in pressure and in temperature that took place in the tubing and the chokes. The amount of fluid collected at the low-pressure separator averaged 20.4 times that caught in the high-pressure separator. The temperatures ranged from 95° to 112° F. above the choke and 50° to 64° F. below it, at the low-pressure separator. The gas-oil ratio, 86,500 cu. ft. per barrel, was not affected by the depth of the wells or by their structural positions. The traces of water condensed above the choke and below it had approximately 800 parts per million of total solids as compared with 28,000 parts per million for the salt water in the same reservoir.

Composite samples of gas taken directly from the tubing showed the following analyses: methane, 92.05 per cent; ethane, 4.37; propane, 1.36; butanes, 0.76; pentanes, 0.25; hexanes and heavier, 0.14; carbon dioxide, 0.10; nitrogen, 0.87. Table 1 gives a comparison between the "oil" and grade 3 gasoline, purchased at a Houston filling station.

TABLE 1.—*Comparison of Motor Fuel X with Agua Dulce "Crude Oil" by Engler Distillation, Et Cetera*

	Motor Fuel Company *X*	Agua Dulce Drip Condensate (Crude Oil?)
	59.1 Gravity Water White	59.8–63.3 Gravity Water White
Boiling Point, Deg. F.		
Initial	102	98–100
10 per cent	162	164–192
20 per cent	192	192–213
30 per cent	220	207–228
40 per cent	246	223–241
50 per cent	268	235–254
60 per cent	286	254–267
70 per cent	306	278–293
80 per cent	327	308–318
90 per cent	354	355–363
95 per cent	384	402–425
End	406	406–440
Recovery, per cent	97.0	96– 97
Residue, per cent	1.2	1.0–1.2
Loss, per cent	1.8	1.7–3.0

Temperature, Deg. F.	Per Cent Over	Per Cent Loss	Per Cent Over
167	11.3	1.8	4.0–11.0
284	59.0	1.8	65.0–73.0
392	95.7	1.8	93.0–94.5

Extracts from the opinion of the court read as follows:[3]

> The contention that they are oil wells is apparently based entirely on the fact that in a separator connected to a choke certain water-white liquid is accumulated, which upon analysis shows to contain various hydrocarbon compounds characteristic of crude petroleum oil. The catching of this liquid is the only thing that could in any possible way be claimed to classify the wells as oil wells. They are not drilled in or produced as oil wells; there is nothing to indicate any fluid level in the formation, or

> any fluid column in the tubing and the casing gives no such indication; the wells do not flow by heads when reopened, nor is there any visible or perceptible liquid given forth at that time. When the wells are opened into the air what is apparently a gas is produced. . . . When this gas is run through a choke and turned into a separator provided with baffle plates, a water-white liquid, heretofore mentioned, is precipitated and saved.
>
> It is our opinion, from the evidence that . . . (these) . . . wells do not produce any crude petroleum oil in the statutory sense of that term. They produce gas, which when acted on by the baffle plates in the separator causes a distillate which complainants claim is oil. It is only by the most strained and technical construction that wells of that character could be classed as oil wells. . . . We think it perfectly obvious that the statutory definition of an oil well was never intended to cover wells of this character, which normally produce gas and can only be made to produce oil by the use of manufacturing processes, however crude, at the head of the well.
>
> Furthermore, it is our opinion that regardless of the question of the manner of production, the water-white liquid caught and saved in the separator is not crude oil within the sense of the Statute defining oil wells. The logs of Complainant's various wells, and other wells in this apparently common reservoir, together with cores and samples of sand from these wells, would indicate that there is no fluid level in the reservoir and no liquid crude petroleum existing therein as such. The sand is uniformly gray in color, contains no fluid and is classified as typical gas and not as oil sand. Liquid caught in the separator becomes such through mechanical devices or condensation after it leaves the head of the well, and not because it existed in such form in the reservoir. If such an operation at the well-head can transform a gas well into an oil well then there are very few fields which should not be classified as oil fields, because the history of the industry, as indicated by the record, shows that volatile liquid . . . can be wrung from practically all gas wells in greater or less amounts. We believe that there enters into the definition of crude oil in all applicable Statutes the proposition that the substance referred to should lie in the bed or reservoir as oil and as oil be produced from it. It was certainly never intended to cover distillates . . . when the Statute speaks of the production of crude petroleum oil. It may be, and possibly is, true that this product of the separator has many of the characteristics of crude petroleum and under certain technical chemical definitions might be so classified. Water-white as it is, and so volatile as to be adaptable for immediate use in gasoline engines, it has certainly never been considered as crude oil by the oil and gas industry generally. We think it manifest that the legislature in speaking of crude petroleum oil meant a liquid existing in the ground as oil and as such produced from it. It is our opinion that this condensate or distillate . . . is not crude petroleum oil within the contemplation of the Statute.*
>
> . . . .
>
> While we are of the opinion that . . . (the) . . . gas is wet and has at some point contacted oil, it is most certainly not at this time produced from an oil stratum, nor is it produced with oil.

It is clear from this decision that one of our most able courts, familiar with oil and gas practices, and backed by long experience in litigation where expert engineers and skilled lawyers have been heard, inclines strongly to the opinion that crude petroleum oil means a liquid, hydrocarbon phase within the reservoir itself. Most engineers would find no fault with this viewpoint for low-pressure fields, or even those in which pressures are below approximately 4000 to 4500 lb. per sq. in. However, recent investigations[4] of high-pressure equilibrium relations make it appear that when the pressures exceed these values, or reach approximately 5000 lb. per sq. in., the attempted demarcation between oil fields and gas fields requires a more discriminating analysis. Each field needs to be considered in the light of the fundamental physical and chemical data that pertain to the contents of the reservoirs. The behavior of the wells at any stage in their history appears to be definitely a function of those fluid properties, which high-pressure and high-temperature studies are making available to the practicing engineer. Interpretation of these facts bears directly on both current and future methods of operating the wells, as well as on questions of well spacing, proration and ultimate recovery.

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* The judges apparently refer to Texas House Bill 266.[1]

Considering field data alone, the most impressive, isolated fact that confronts the student of modern deep reservoirs is the fact that in many fields the wells have a constant, or nearly constant, gas-oil ratio, regardless of their sand penetration and their position with reference to the geologic structure. The field data can best be correlated with the fundamental research work conducted under the leadership of Dr. William N. Lacey,[5] sponsored by the American Petroleum Institute, and by Brown, Katz and their associates.[6] Their studies of mixtures of pure gaseous hydrocarbons with pure liquid hydrocarbons under high pressures resulted in either increased or decreased liquid volumes, depending upon the original volumes of liquid with which the experiments started. Either the gas—methane—went into solution in the liquid phase of propane, pentane, or other hydrocarbon, or the liquid propane, pentane, hexane went into solution in the gaseous phase, depending upon the concentrations, the pressures, and the temperatures. The range of pressure within which both phases could be present was limited by both the temperature and the composition of the mixtures.

Imagine our deep reservoirs—or those at high pressures—to be something of this same sort, but instead of gas composed of a single component, let the approximate molar composition of the gas mixture be represented by x and that of the oil by y. During geologic time, the pressure and temperature probably varied and both increased and decreased, either during or after the accumulation of the reservoir contents. Some degree of equilibrium has been reached, which prevails when the reservoir is penetrated by the drill. An oil field or gas field or combination of the two may have resulted, depending on the temperature, pressure, and the concentrations of the x and y constituents available. For example: (1) All of the oil or y component, if any was present at some time during geologic history, may have gone into solution in the gas phase x, with the result that the reservoir is—when tapped—a gas-bearing one, or a single-phase type with no oil present in the liquid phase; or (2) the concentration of the gas phase may have been sufficient not only to saturate the oil but also to provide a surplus, which resulted in the familiar gas cap, i.e., a two-phase field; (3) if the pressure exceeds that required to saturate the oil with the kind and quantity of gas available, no gas cap is found—i.e., a single, liquid phase exists at the initiation of development. Each case, however, represents merely the combination of the different variables—concentration, temperature, pressure—into an equilibrium relation, which is disturbed when the reservoir is tapped.

CASE 1

Considering only the hydrocarbons, imagine that a high-pressure reservoir with a constant gas-oil ratio has been penetrated by the drill. All of the wells produce "dry" gas or have a very high gas-oil ratio. The ratio of gas to condensate varies for different fields, ranging from 10,000 to 200,000 cu. ft. per barrel, but this merely means that the fields produce mainly gas. The small amount of condensate recovered was dissolved in the gas under reservoir conditions, and condensed at the surface under certain reduced temperature and pressure conditions as distillate, drip condensate, or drip gasoline. This type of condensation, whereby the dewpoint is reached by reduction in pressure, is known as retrograde condensation. The more familiar type of dew formation results from an increase in pressure, at relatively low pressures and constant temperatures. It is possible that the uniform gas-oil relation or the single-phase reservoir may persist as such until the reservoir pressure has been lowered to a point where, if the temperature is low enough, oil may begin to condense within the sand itself, and the field may then pass from the stage of a gas field into one where it is actually an *oil and gas* field, if an oil field be considered one in which the hydrocarbons of the reservoir are in the liquid phase. Even this condition may be only temporary, and if the pressure continued to fall the field may, or may not, depending upon the concentration of its components and the prevailing temperatures, pass over once more into the stage of an ordinary gas field as the term is commonly understood.

Eventually the question will arise as to how to produce such a reservoir when it reaches the stage where it possesses both gaseous and liquid hydrocarbons. Answers to this inquiry will be influenced by the quantity of the liquid phase, the degree of adsorption of the latter by the sand grains, and the available pore space, but even more important will be the presence or absence of an active water drive. On the one hand, an active water drive would, by maintaining the reservoir pressure, tend to prevent the formation of a liquid hydrocarbon phase; on the other hand, it is entirely conceivable that water encroachment might aid in the production of a liquid phase if a high differential pressure is required to stimulate active water drive, and the critical pressures are nearly equal to the reservoir pressure. These relations will vary for each reservoir, just as the composition of the gases and heavier hydrocarbons will vary, though the general principles still seem sound. It is entirely possible that commercial production of the liquid phase may become impracticable, because of the large quantities of condensate required to wet the sand grains; some condensate will adhere to them under almost all known operating conditions. If no oil is present in such a field at the time of discovery, sound conservation will demand that it be operated as a gas field, since the flow of the single phase through the sand will follow the equation of Pierce and Rawlins,[7,8] or be proportional to the difference in pressures squared.

Since deeper drilling normally means higher pressures, the probabilities are that deeper fields—even to 8000 to 10,000 ft.—will be more and more likely to have a high gas-oil ratio, or to be gas fields, since both higher temperature and increased pressure tend to reduce the range within which both gas and oil phases can exist together. The relative proportion of lighter constituents will also tend to increase. This was recognized by Barton several years ago:[9]

> In sands of the same age, there is an increase of the lighter constituents and of the A.P.I. gravity and decrease of the heavier constituents with depth. In sands of the same depth, there is increase of the lighter constituents and of A.P.I. gravity with increasing age. . . . Under the effects of pressure and temperature (as a function of depth) and of time, there is produced a progressive transformation of the heavier constituents into lighter constituents.

CASE 2

If, at the time the reservoir was penetrated, the proportional quantities or molecular concentrations of the two phases were such that, even though gas had gone into solution in the oil and saturated it at the temperature and pressure of the reservoir, some of the gas phase still remained, the field is initially one with a gas cap overlying the crude oil—a two-phase reservoir. This is the type of oil and gas field that has provided the great bulk of our crude oil, but the anticipation that such fields will continue to be discovered at greater and greater depths appears to be fallacious.

CASE 3

If the concentration of the gas phase happened to be so small in proportion to that of the liquid phase that the former has been completely dissolved under the pressure and temperature conditions prevailing at the time of discovery, no gas cap will exist until the pressure in the field has been so reduced that the gas can come out of solution and establish equilibrium between the two phases. East Texas is the type field of this character.

CONCLUSIONS

From the preceding discussion, it follows almost necessarily that allocation of the fields with high pressure and high gas-"oil" ratio should be based on such sound principles as apply to the operation of gas fields. The amount of "oil" or condensate produced with gas for which a market exists should constitute the limiting oil allowable; to produce the oil—or condensate—for itself alone, while the gas is blown to the air, is unsound engineering and waste, both of the irreplaceable resource and its energy. Incidentally, the single-phase gas reservoir may possibly be maintained through the introduction of water well down on the flanks of the structure. Attention should be directed to the merits of repressuring or cycling the "stripped gas." Such recycling process must be regarded as sound engineering practice, since it ensures recovery of the "heavy ends" present in the gas phase; no other known process will recover them with as much certainty and as little expense.

If, on the other hand, the field is the single-phase type, where gas is dissolved in the oil and no gas cap exists, it should be operated as an oil field, the energy of the dissolved gas and encroaching water used to lift the oil, the gas-oil ratio restricted to the minimum, flank repressuring practiced, the rate of production restricted so as to prevent the formation of a gas cap, potentials abolished as a basis for allocation, and every sound engineering practice utilized with a view to increasing the amount of hydrocarbons that may be recovered.

If the reservoir that was at first a gas field should later become an oil field (which is only a remote possibility), it may be necessary to recognize such a transformation and modify the basis of allocation. Given sufficient information, it should be possible to predict from high-pressure experimental data as to equilibrium relations, together with comprehensive analyses of cores, determinations of porosity and permeability, and adsorption coefficients, whether or not enough liquid hydrocarbons will collect in the sand to cause liquid hydrocarbons to issue at the well head; i.e., to make the field an oil field. Here again an active water drive might bring on a period of oil production, even though the quantity of liquid present were small. Both high-temperature water and high salinity will tend to help in such recovery.

The net result of this analysis as applied to fluid behavior in high-pressure reservoirs is to stress the importance of the early acquisition of physicochemical data such as equilibrium constants, critical pressures and temperatures, concentration of the various constituents, together with reservoir temperatures and pressures.

Without apprehension, the writer ventures the opinion at this point that we are now, at least on the Gulf Coast, very close to the limiting depth at which two-phase hydrocarbons will be encountered. Phrased in other terms, it is very doubtful that deeper drilling will result in the discovery of important oil fields below 12,000 or 13,000 ft., though these limits will be partly dependent on the thermal gradients in the particular area. On the other hand, deeper gas fields may be expected, but they must be recognized as gas fields, not oil fields.

Practically, these data bear definitely on the problem of well spacing, since it has been amply demonstrated that the drainage areas of gas wells are extensive,[10] and hence close spacing with its accompanying high capital expenditures should be studiously avoided until economic conditions can or may justify it. The behavior of wells and their spacing densities should also be looked at in the light of our relatively recent but perfectly sound concept that the ownership of oil and gas pertains fundamentally to oil and gas in place.

Gas reserves, or reserves in the gas phase, can be readily estimated and equity as between the various operators can be established with little difficulty. The problem is somewhat more complicated in connection with oil, but such estimates can also be made with reasonable accuracy, provided the essential data are obtained. The operating agreements between various groups in a field should always be flexible enough to anticipate the possibilities of pressure maintenance and changes in phase of the reservoir contents.

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DISCUSSION

(T. V. Moore presiding)

P. Weaver,* Houston, Texas.—The prediction that two-phase fields will not be discovered below 12,000 to 13,000 ft., I think, is sound, with one exception—if there were an unconformity, whereby there might at some time in the past have been a leakage of light phase, resulting in a low gas-oil ratio at that time. Even if such a field were subsequently buried to depths greater than 12,000 ft., it would be a two-phase field, because the solution of oil in gas requires, in addition to high pressure in the reservoir, a high gas-oil ratio, and the greater the density of the liquid, the greater this gas-oil ratio must be for complete solution of the oil in the gas at a given temperature and pressure.

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* Geologist, Gulf Oil Corporation.

T. V. Moore,* Houston, Texas.—I think that we will always have two phases. One phase may be a heavy tar.

E. A. Stephenson.—The points raised by Mr. Weaver serve to emphasize the fact that the geological history of an area has an important bearing on the development and operating procedures, and the earlier the geological history can be deciphered the less time and money are likely to be misspent.

M. Lee,† Wichita, Kansas.—Professor Stephenson mentions laws of nature and man-made state laws, which some judges and legislators do not thoroughly understand. The technical language of our meetings gets into the laws. The Kansas law for repressuring oil wells uses the word "fluid" when evidently it was the intent of the legislators to mean liquid or water only. The State Corporation Commission finds that it must comply with the law and observes that fluid means any liquid and also oil and gas. In writing or discussion, engineers can help the legislators and the courts by describing liquids or fluids properly. If we fail to do this, we should not blame the legislators or the courts for their misunderstanding of technical terms or their application in production practices.

G. Wade,‡ Dallas, Texas.—Professor Stephenson's paper is of special interest in that it generates thought on the significance that the physical properties and state of the petroleum in the reservoir may have on the choice of method of development and operation of the field. Under Case I, consider that an exploratory well is being drilled, that drill-stem tests are being made (to points where pressures are not too great for carrying out that operation with reasonable safety), and that progressive drill-stem tests yield only gas: Can it be expected that examination of samples of this gas in the light of the method that Dr. Katz has discussed will reveal the probable state of the petroleum in that reservoir and thus provide guidance for planning the development program for the field?

D. L. Katz,§ Ann Arbor, Mich.—As the data on critical properties of hydrocarbon mixtures grow, one should be able to predict the reservoir phases from an analysis of a well effluent, the reservoir temperature, and the reservoir pressure.

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† Petroleum Geologist.

‡ U. S. Bureau of Mines.

§ Assistant Professor, Chemical Engineering, University of Michigan.

Connate Water in Oil and Gas Sands

By Ralph J. Schilthuis,* Junior Member A.I.M.E.

(Oklahoma City Meeting, October, 1937)

Several investigators[1–8] have reported evidence of the existence of native or connate water in oil-and-gas-bearing strata. Both water and salt have been detected in cores of oil sands that yielded oil and gas exclusively when produced. Electrical logs often reveal unexpectedly low resistivity through oil and gas sands, indicating the presence of some material that is a considerably better conductor of current than oil and gas. Furthermore, calculations[9] of the oil and gas content of reservoirs based upon production and reservoir-pressure decline data indicate appreciably lower values than are arrived at under the assumption that the pore space is occupied completely by oil and gas.

Origin and Occurrence of Connate Water in Oil-and-gas-bearing Formations

The view has been expressed,[10–15] and is generally agreed upon, that the expulsion of oil and gas material from source beds and the subsequent migration and accumulation occurred in the presence of salt water. As the strata that usually form reservoirs for oil and gas were laid down by, or in the presence of, ancient seas, the pore space within the strata must have been saturated with salt water before the entrance of the oil and/or gas. Thus, the accumulation of oil and/or gas in the upper regions of structures suitable for reservoirs must have required displacement of the connate water therefrom.

In the absence of any forces other than gravitational, it would be expected that the displacement of the connate water out of the zones finally occupied by gas and oil would be complete, and that the vertical distribution of gas, oil, and water in a reservoir would be strictly in the order of their densities. Apparently, however, surface and interfacial forces that will not permit complete segregation of the fluids are active within the capillary spaces comprising a reservoir. The effects of these forces on both accumulation and production of oil and gas have been the subject of study by a number of investigators.[16–37]

In general, the view is held that the character of most materials that make up the reservoir rock leads to preferential wetting of the rock by

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* Humble Oil & Refining Co., Houston, Texas.

[1] References are at the end of the paper.

water instead of by oil. The resistance to displacement of water by either oil or gas from capillary spaces increases as the cross-sectional dimensions of the pores decrease. The displacement of the water can proceed only to the point where equilibrium is reached between the surface and interfacial forces that resist the displacement and the forces that favor it. Thus, conditions of occurrence of the fluids within the oil-and-gas-bearing zones of reservoirs are probably such that:

1. The reservoir rock is completely wet by connate water and does not contact either oil or gas directly.
2. Oil and gas exist in the larger and interconnected pore spaces.
3. Connate water completely fills the smallest crevices and capillaries, particularly those that are discontinuous or sealed entirely.

The vertical distribution and the relative concentration of the fluids within certain zones probably is influenced by several factors; e.g., the relative densities of the fluids, size of the pore spaces, and interfacial and surface effects, the latter being dependent upon certain physical and chemical properties of the fluids and of the reservoir rock. Production experience bears out the fact that usually a well defined so-called "water-oil level or contact" exists, above which oil is obtained and below which water is produced either with the oil or exclusively. However, the fact that oil can be produced without water does not prove the absence of water in the oil-bearing formation. Brace[2] writes: "Within a producing area, the fact that the produced oil is clean is no index as to the presence or absence of moisture in the sand, since the forces that held the water in place during oil migration would perform the same function during oil extraction." Whereas there was some question of Brace's view, later investigation supports it. While there is usually a fairly definite boundary or limited zone above and below which oil and/or gas or water, respectively, is produced exclusively, it is likely that there is no level above which only oil and gas exist within the pore spaces. In a given reservoir, the so-called "water table" is probably defined by a relatively narrow zone below which the ratio between the water and oil saturations is high enough so that only water is produced, while at higher levels, where the oil saturation is greater, oil production is obtained. When the properties of the formations are uniform, the limiting water-oil saturation ratio probably is definite.

The permeability of reservoir rock is closely related to the size of the pore spaces. It can be shown from Poiseuille's law that the permeability for a given fluid and given porosity varies as the square of the cross-sectional dimensions of the pore spaces. If the views are correct that the degree to which oil and gas displaced the connate water out of the pore spaces in accumulation is limited by size of the pores, it follows that the connate-water content of oil and gas formations should bear some inverse relationship with their permeabilities. Evidence that this is true will be presented.

DETERMINATION OF CONNATE-WATER CONTENT OF OIL-AND-GAS-BEARING FORMATIONS

The only means yet developed by which the connate water and oil content of formations can be quantitatively estimated is through examination and analysis of cores. Reliable methods have been worked out and described [38,39,8] to determine both the water and oil content of core samples. However, in order that the analyses of such samples shall correctly reflect conditions, quantitatively, as they exist within the formations in place in a reservoir, it is usually necessary to employ special technique in coring and to observe precautions in preservation of the samples until analyzed.

Difficulties of Obtaining Representative Samples.—The principal difficulties that stand in the way of obtaining core samples of which the fluid content represents conditions existent within a reservoir are: (1) contamination and flushing of the cores by the drilling fluid or liquid phase therefrom; (2) reduction of pressure occurring as the cores are withdrawn from the well and resulting in expulsion and loss of portions of the native fluids.

In drilling and coring a high-pressure formation, it is necessary to maintain the density of the drilling fluid to keep the pressure exerted somewhat higher than the pressure in the formation. The differential pressure can produce either or both of two effects on the cores: first, contamination by infiltration of the drilling fluid or water therefrom about the periphery as the cores are cut; second, flushing or displacement of the native fluids out of the formations subsequently cored by the downward penetration or filtration of the liquid phase of the mud through the formations ahead of the advance of the drill and core barrel. Experience[40] indicates that the latter effect is probably the most serious and difficult to cope with.

The effect of reducing the pressure upon the cores and their contents during removal from the well is always to cause complete loss of gas and a further loss of any oil that may be present. On the other hand, because of the mechanism by which connate water exists within oil-and-gas-bearing strata, it is unlikely that any appreciable amount of any loss in connate water from a core occurs on account of reduction of pressure, except where the water saturation is very high. No technique has ever been developed to correct for or to prevent the losses of oil and gas arising from the release of pressure. Thus, determinations of oil content on core samples must usually be considered minimum values as far as actual conditions within a reservoir are concerned.

To correct for contamination of cores by the drilling fluid or aqueous phase thereof, the procedure has been suggested and used[4,8] whereby "tracers" have been placed in the mud, and their subsequent quantitative detection in the cores has been taken as a measure of the water originating from the drilling fluid. Acetone, arsenic, propanol, and dextrose treated with octanol to prevent fermentation have been used as tracers. While such technique would permit measurement of contamination if it arose simply from radial infiltration of small amounts of the aqueous phase of the mud into the cores after they were cut, the method cannot reveal the degree to which the fluids native to the core might be displaced or swept out by advance of the liquid phase of the mud through the formations before they are penetrated by the core barrel. The latter is very important in connection with highly permeable strata where any moderate differential exists between the pressure exerted by the drilling fluid and the formation pressure. Where aqueous drilling fluids are used, the advance of the water therefrom not only sweeps out a part of any oil present but also reduces the concentration of dissolved salts in the connate water so as to preclude measurement of connate water either directly or indirectly through analysis for native salts.

Use of Oil-base Drilling Fluid.—It would seem reasonable that the use of a water-free drilling fluid might overcome some of the difficulties encountered in obtaining representative samples of oil-and-gas-bearing formations for determination of their connate-water content. An oil-base mud has been successfully used for this purpose. True, the determinations of the oil content of core samples obtained while using such a mud are open to question, yet, because of the very nature of its occurrence, the connate water is undisturbed, except in highly permeable formations where penetration of oil from the mud ahead of the drill might be sufficiently severe to flush away a portion of the water if water saturations are high. This difficulty might be experienced in the vicinity of the so-called "water-oil contact" or below, but ordinarily not in the zones actually productive of oil and gas.

An oil-base drilling fluid prepared from the native crude oils weighted with oil-wet clay has been employed in coring the gas and oil zones of the Anahuac and Tomball fields, in the Texas Gulf Coast area, and in the East Texas field. The weighting material was spent clay, which had been used in the refining of motor oils. The fluid was treated with about 0.5 per cent of oleic acid and 1 per cent of sulphuric acid (98 per cent), by volume, to aid dispersion of the clay and to increase the tolerance to water. Litharge was used where necessary to increase the mud density.

Preservation of Core Samples.—Immediately upon reaching the surface, samples of the cores were selected, scraped to remove the clay sheath, and then coated with synthetic wax to preserve the contents against evaporation. Ordinary sealing wax, such as is used for sealing letters, was chosen after tests of paraffin wax, waxed paper, cellophane, collodion and lacquer. Sealing wax best withstands handling, indefinitely resists penetration or solution by the core contents, and yet is easily removed.

The core samples were analyzed for water, oil, and sodium chloride content. Determinations were also made of porosity, permeability, and bulk density of an extracted and dried piece taken from each core sample adjacent to that used for the oil, water, and salt analyses. The analysis for water serves as a direct measure of the connate water while the analysis for sodium chloride, coupled with data on the analyses of native salt water produced from the field, is an indirect check on the direct measurement of connate water.

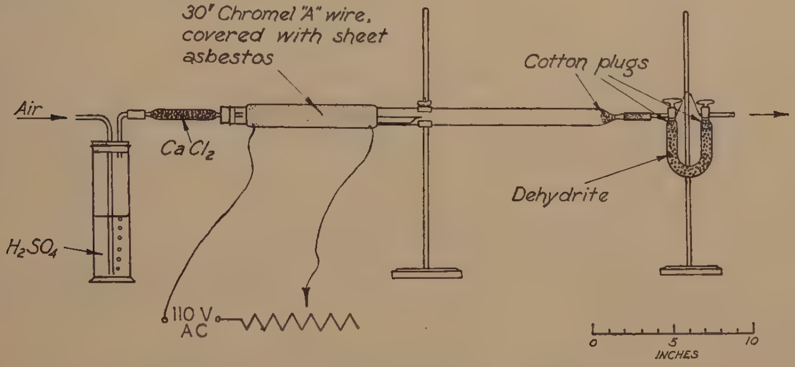

Fig. 1.—Apparatus for determination of water and oil in cores.

Determination of Water and Oil.—A procedure differing somewhat from those previously described[38,39,8] was employed to analyze for the connate water and oil content of the samples. The method combines vaporization and combustion, having provision to absorb quantitatively the water vaporized and to give a measure of the oil by the difference between the total loss in weight of the sample after combustion and the weight of the water vaporized and absorbed.

A sketch of the apparatus is shown in Fig. 1. It consists of a Pyrex glass tube about 1 in. in diameter and 25 in. long, fitted with a heating element as shown. One end is attached to a source of dry air and the other to a U-tube containing anhydrous magnesium perchlorate (Dehydrite).

In the analysis, a 5-gram portion of the crushed sample is weighed out into a small porcelain boat and the boat is inserted into the apparatus and placed slightly beyond the heating element as shown in Fig. 1. The Dehydrite tube is also weighed and placed in position, then a slow current of dry air is allowed to pass through the apparatus. Temperature is adjusted to between 125° and 150° C. Usually some water condenses in the cool downstream end of the heating tube, and therefore the air must be passed for a sufficient time to completely drive all water over into the absorption tube. The cotton plug in the constricted end of the heating tube traps any oil spray, preventing it from entering the absorption tube.

After the water has been expelled from the sample (requiring usually 45 to 60 min.) the Dehydrite tube is removed from the system and weighed to determine water. At the same time, temperature is raised to about 425° C., sufficient to burn and expel all oil in the sample in presence of the dry air stream. The loss in weight of the sample minus the weight of water determines the oil.

The method is rapid and does not require calibration to correct results for losses or for water of constitution, which is driven off the core material in some methods employing higher temperatures.

Determination of Chloride.—The determination of chloride is made on a portion of the sample crushed for water and oil analysis. A 5 to 15-gram sample is weighed out and digested in about 100 ml. of water and 5 ml. of saturated potassium nitrate, the purpose of the latter being to coagulate clay particles. The mixture is heated to boiling, then allowed to stand for a time before it is filtered; the filtrate is titrated with standardized silver nitrate solution, using potassium chromate as indicator.

The chloride determination must be made on a portion of the sample separate from that used for water and oil analyses, as investigation indicates a 15 to 25 per cent loss of salt in the course of the vaporization and combustion.

Determination of Permeability, Porosity, and Bulk Density.—Permeability, porosity, and density measurements are made on the same sample after sizing, leaching with solvents such as alcohol, carbon tetrachloride, and ether to remove connate water and oil, and then drying. After the dried sample is weighed for the bulk density measurement, permeability is determined in accordance with A.P.I. Code No. 27, the effective volume of pore space by the Washburn-Bunting method,[41,39] and finally bulk volume by displacement of mercury from a pycnometer.

RESULTS OF CORE EXAMINATION AND OTHER TESTS

The data obtained in the examination of cores taken with use of an oil-base drilling fluid, from two wells in the East Texas field and a well each in the Anahuac and Tomball fields, are presented in Figs. 2 to 5. Electrical logs and temperature gradients are included, where obtained, for comparison with the core data. The East Texas field produces from the Woodbine sand, the Anahuac field from a sand of the Marginulina and Frio formations, and the Tomball field from a sand of the Cockfield formation.

Well No. 1, *East Texas Field.*—Fig. 2 shows that the connate-water saturation averages 6 to 10 per cent in the sand sections through the entire oil zone of well No. 1 except in the section below a depth of about minus 3297 ft., where it averages probably greater than 30 per cent.

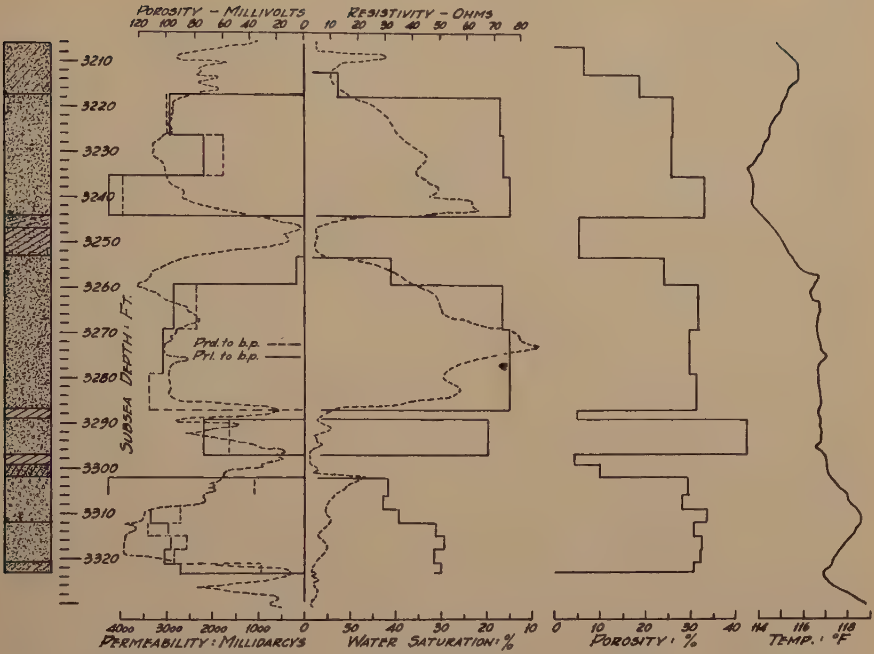

FIG. 2.—CORE DATA AND FORMATION LOGS FOR WELL NO. 1, EAST TEXAS FIELD.

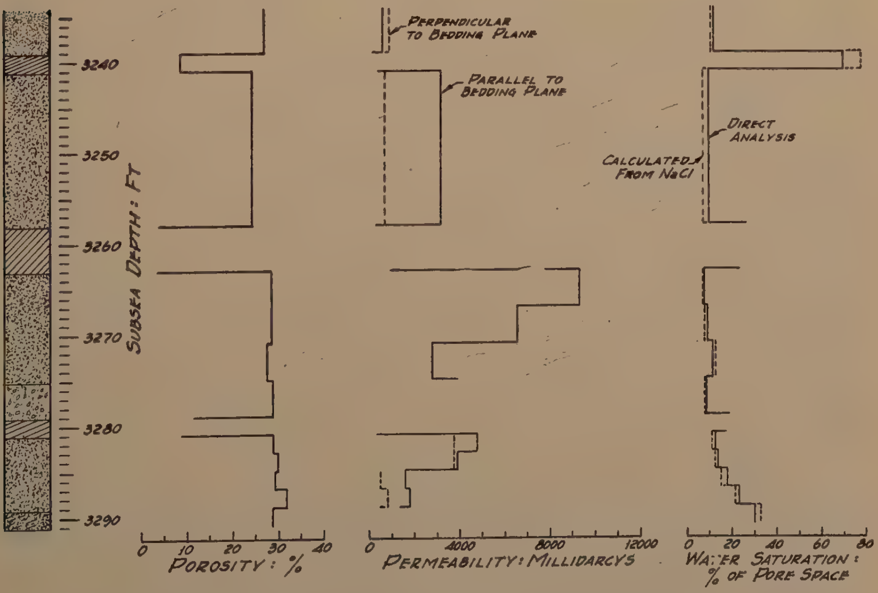

FIG. 3.—CORE DATA, WELL NO. 2, EAST TEXAS FIELD.

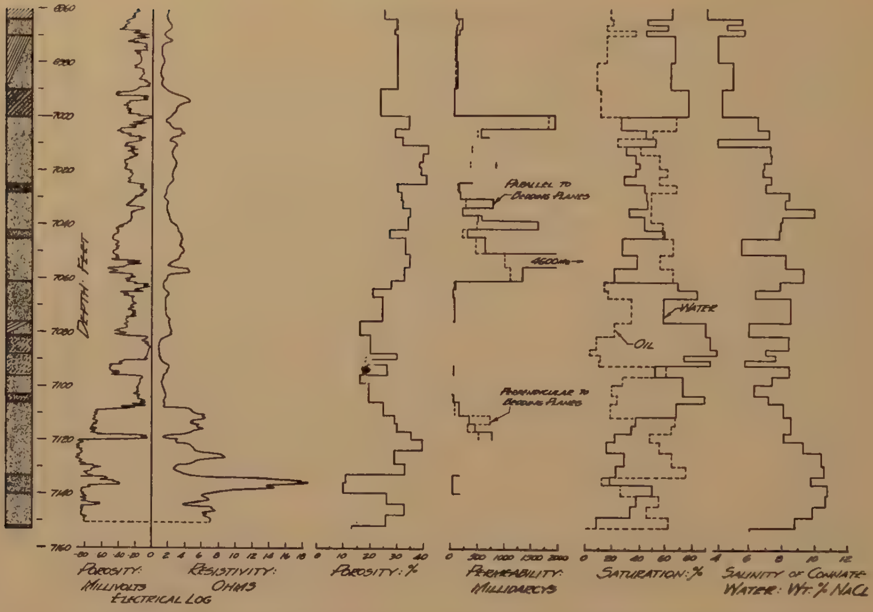

FIG. 4.—CORE DATA AND FORMATION LOGS, ANAHUAC FIELD, CHAMBERS COUNTY, TEXAS.

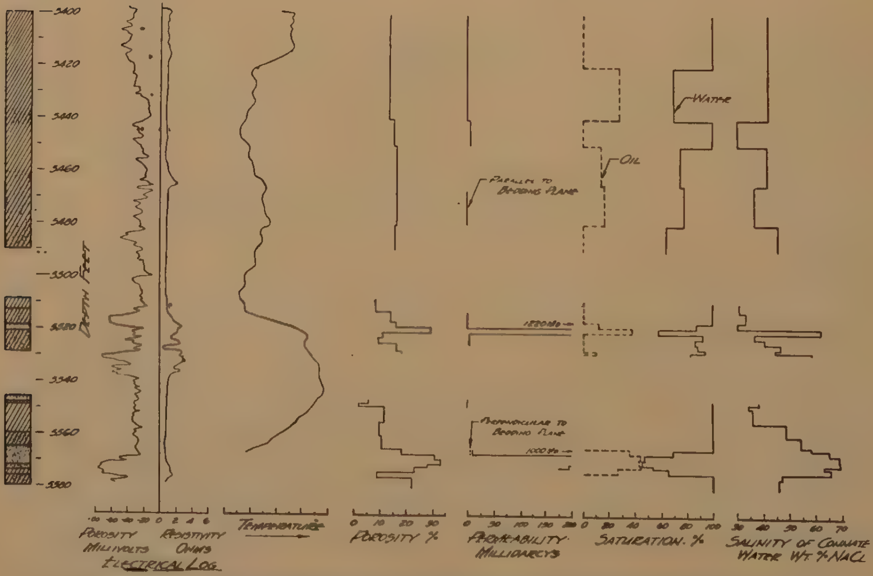

FIG. 5.—CORE DATA AND FORMATION LOGS, TOMBALL FIELD, HARRIS COUNTY, TEXAS.

There is good qualitative correlation between the water saturation of the cores and the electrical resistivity log, except below about minus 3301 ft., where the water saturation does not increase proportionately to the decrease in resistivity shown. On a drill-stem test of the section minus 3307 to 3311 ft., the well flowed 26 per cent salt water, indicating intrusion of water and at least partial flooding as high as 9 ft. above the original so-called "water-oil contact," commonly considered as 3320 ft. subsea. The well was completed, making 100 per cent oil, in the section from minus 3291 to 3295 ft. The high permeability of the section below minus 3301 ft. permitted oil from the drilling fluid to penetrate the cores thoroughly and thus flush away a portion of their water content.

There is a rough parallelism between the electrical porosity log and the actual permeabilities and porosities of the cores. The highest potentials are observed in the most permeable and porous sections.

Well No. 2 East Texas Field.—The general nature of the information obtained on the cores from well No. 2 (Fig. 3) is the same as for well No. 1. The connate-water saturation averages about 10 per cent throughout the oil section to a depth of minus 3285 ft., below which it increases gradually to more than 30 per cent. There is good correlation between the water saturation determined directly and that calculated from the analysis for chloride. The well was completed with the entire section open to production and making 100 per cent oil.

Anahuac Field.—The core data and formation logs obtained at Anahuac are plotted in Fig. 4. The connate-water saturation of the entire gas-and-oil-bearing zones is very high, ranging from a minimum of 16 to as high as 98 per cent. Connate water occupies 50 per cent, on the average, of the pore volume in the oil section, 7019 to 7120 ft., and possibly a slightly higher percentage in the gas zone, 6940 to 7019 feet.

The salinity of the connate water found within the cores from the lower parts of the oil section checks closely with the salinity of salt water produced in the field. However, in the upper regions, the salinity of the connate water decreases markedly, especially in the gas zone. This may be due to a continuous process of distillation and diffusion proceeding within the reservoir, actuated by the earth-temperature gradient. It is conceivable that such an effect might in general result in higher water saturation in a gas zone above an oil zone than in the oil zone itself.

A fair general correlation exists between the electrical porosity log and the actual permeability and porosity logs of the cores. Further, the resistivity log bears a general inverse relation to the connate-water content of the cores. The unusually low resistivity through the gas zone and the bulk of the oil zone, in spite of any possible effects of the oil drilling fluid, is probably accounted for by the high connate-water saturations.

A series of five drill-stem production tests was conducted within the section from 7116 to 7151 ft. The first test was made from 7149 to 7150¾ ft., the second from 7139 to 7141 ft., the third from 7132 to 7134 ft., the fourth from 7125 to 7127 ft., and the last from 7116 to 7118 ft. The first four tests yielded only salt water, but the fifth produced 100 per cent oil. The tests definitely limited the zone of transition from oil-producing to water-producing sand to the section between 7118 to 7125 ft., indicating that while no plane or table exists above and below which oil and gas exist in the formation exclusively, there is a fairly definite level, probably determined by a certain water-oil saturation ratio peculiar to the properties of the particular formation, at which one or the other of the fluids is produced exclusively.

It is observed that the connate-water saturations below about 7120 ft. are relatively low and thus incompatible with the results of the first four drill-stem tests. This is explained by the fact that the formations below about 7110 ft. were highly permeable and poorly consolidated, permitting serious contamination by oil from the drilling mud. It is noted that the electrical resistivity is highest in the sand that actually yielded 100 per cent salt water, showing that contamination proceeded to the degree that water was displaced from the formations adjacent to the well bore, replaced by oil, and the resistivity thereby increased.

Tomball Field.—Fig. 5 contains the core data and formation logs for the Tomball field. The general character of the data, although less complete, is the same as that observed in the Anahuac field.

Somewhat higher connate-water saturations are indicated than were observed at Anahuac, a condition that is compatible with the relative permeabilities of the formations in the two fields. The average water saturations of the two sand sections from which cores were recovered are 59 and 49 per cent. Again the formations show unusually low resistivity, a result undoubtedly related to the high connate-water content.

Practical Significance of Connate Water

Relation between Permeability and Connate-water Content.—All data on permeability and connate-water saturation given in Figs. 2 to 5 are plotted in Fig. 6. A rough correlation between the water saturation and permeability is noted. The relation is inverse, the water saturation being least in formations of high permeability and greatest for low permeability. The converse would be true of the oil saturation, where oil is present. The lower the permeability, the more marked is the influence of permeability on either the water or the oil content.

Fig. 6 shows that the Anahuac and Tomball data plot together while the East Texas data have an individual trend. For the same permeability, the sands in the Anahuac and Tomball fields carry much larger quantities of connate water than the East Texas Woodbine. This probably illustrates the influence of differences in the properties of the formations and of the fluids. Within the range of permeability from

50 to 500 millidarcys, the data show an average of 2½ times greater water content in the two Gulf Coast fields than in the East Texas field.

Influence on Oil and Gas Reserves and Recovery.—It is reasonable to assume that under original conditions the part of the pore space within oil-and-gas-bearing strata not occupied by connate water must be filled with oil or gas. It has been observed that the water saturation is an inverse function of permeability. The oil or gas saturation must, therefore, be some direct function of permeability. Based upon the data in Fig. 6, Table 1 is given to show the probable relation between original unit oil content and permeability for the three fields studied. The most

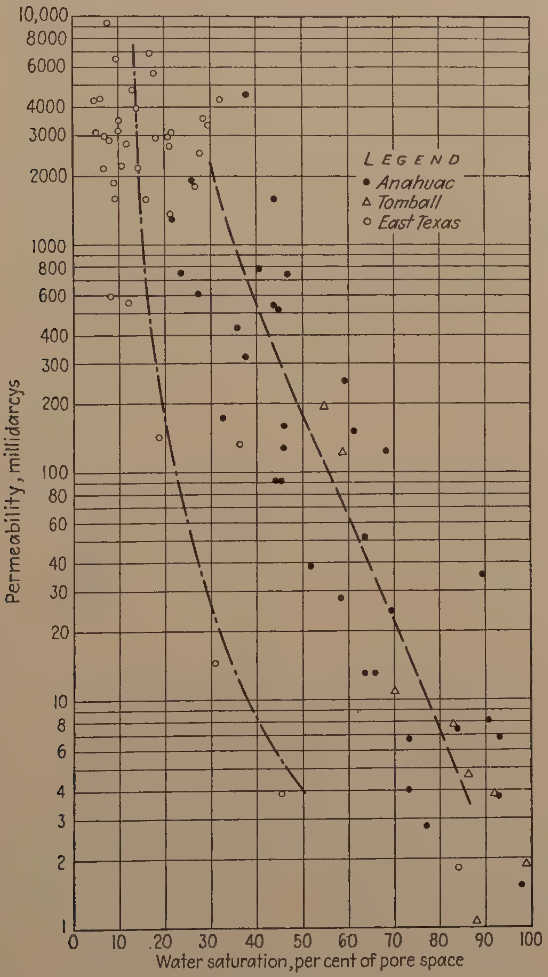

FIG. 6.—RELATION BETWEEN PERMEABILITY OF CORES AND CONNATE-WATER SATURATION.

significant point concerning this table is that sands having identical permeability may contain widely different quantities of oil. The difference is due to variance in other properties of the reservoir rock and in the properties of the fluids involved. The fact that for the same porosity there may often be a marked variation in oil saturation, either for reason of difference in permeability or other causes, has an important bearing upon reserves and recovery of oil. It is common practice to base estimates of oil recoveries purely upon acre-foot yields experienced in fields considered similar to that on which the estimate is made. Without the aid of more information than is usually at hand, this is likely to be a dangerous procedure. Two fields may differ only slightly in operating characteristics in early life but may have distinctly different unit oil saturations and thus may yield entirely different unit ultimate recoveries.

TABLE 1.—*Probable Relation between Original Unit Oil Content and Permeability*

Permeability, Millidarcys	Oil Content in Place			
	Saturation, Per Cent		Barrels per Acre-ft. at 28 Per Cent Porosity	
	East Texas	Anahuac Tomball	East Texas	Anahuac Tomball
10	62	23	1350	500
100	78	44	1690	960
1000	85	65	1840	1410
2000	86	69	1870	1500

It is believed that too much emphasis cannot be placed upon the need to use the utmost precaution in predicting recoveries on current or new fields based upon experience in old fields. The older fields are much shallower in general than those now being produced and developed. On account of their shallower depth, the formations probably possess somewhat greater porosity and permeability and in consequence lower content of connate water and higher original oil saturations than presently operated fields or those which may be developed at greater depth in the future. Records on depleted fields or those now in the last stages of production indicate that a number have given recoveries of 800, 900 and occasionally more than 1000 B/acre-ft. The data presented in Fig. 6 indicate that the minimum average connate-water saturation even at extremely high permeability is probably upwards of 10 per cent. Assuming only 10 per cent water saturation, or 90 per cent original oil saturation for the oil fields, an oil shrinkage of 10 per cent, and 28 per cent porosity, a 900 B/acre-ft. yield means that slightly over 50 per cent recovery of the original oil was often obtained. In some of the current fields where water saturation apparently approaches 50 per cent, it should be significant that the volume of oil in place is but little higher than the recoveries recorded in old fields. If the current and future fields are to equal the reported yields of old fields, the percentage recovery will need to be extremely high.

It has been observed that connate water exists in gas-bearing formations to the same or possibly even greater degree than in oil-bearing formations. Unless the presence of water is accounted for in estimating gas reserves by the porosity-volume method, a percentage error equal to the water saturation will be made. The magnitude of the error introduced by ignoring connate water in estimation of gas reserves may be even greater than in estimation of oil reserves.

Secondary Recovery.—The prevalence of appreciable quantities of connate water in oil-bearing formations throws a somewhat different light on both the actual unit quantities of oil and gas originally in place in the ground and the efficiency attained in oil recovery. This is important in consideration of secondary methods of recovery such as water-flooding or repressuring. The need of knowing the facts concerning the presence and amount of connate water before undertaking such programs has already been discussed.[7,39]

Influence on Operations.—There has been considerable speculation as to the possible influences of connate water upon the various operations associated with the production of oil and gas. It is known that the presence of high concentrations of water in oil-and-gas-bearing formations reduces their sensitivity to detection either by visual examination of cores or by electrical methods of logging. Furthermore, it is known that the permeability of sand to oil is considerably reduced when relatively large amounts of water are contained within the pore spaces. Water saturations up to 10 to 15 per cent have little effect, but saturations exceeding these limits markedly deter flow.

There is both experimental evidence and field experience to indicate that a fairly definite oil-water saturation ratio exists for a system of given properties, which determines whether oil will be yielded exclusively or accompanied by the water. The existence of such a limiting value may become important in the production of sands that are highly saturated with connate water. It may be possible in some instances that only a relatively small quantity of the oil need be removed before the point would be reached where the entire formation would produce both oil and water. This might require early artificial lifting and production of great quantities of water before all the oil that it might be possible to recover is obtained.

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DISCUSSION

(*R. L. Huntington presiding*)

W. S. WALLS,* Bartlesville, Okla. (written discussion).—The practical significance of connate water in primary and secondary oil-producing operations is of considerable importance in the estimation of oil and gas reserves and recovery. In secondary operations cores of oil-bearing formations are subjected to laboratory analyses for the purpose of determining sand characteristics and for the estimation of probable oil recovery. Ordinary laboratory determinations of oil and water saturation of cores frequently fail to permit a satisfactory estimate of recoverable oil present in the core due to the influence of connate-water saturation on the amount of residual oil that will remain in the core after being subjected to flooding operations. This influence is indicated when cores containing their natural saturation are subjected to laboratory flooding tests.

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* Phillips Petroleum Co.

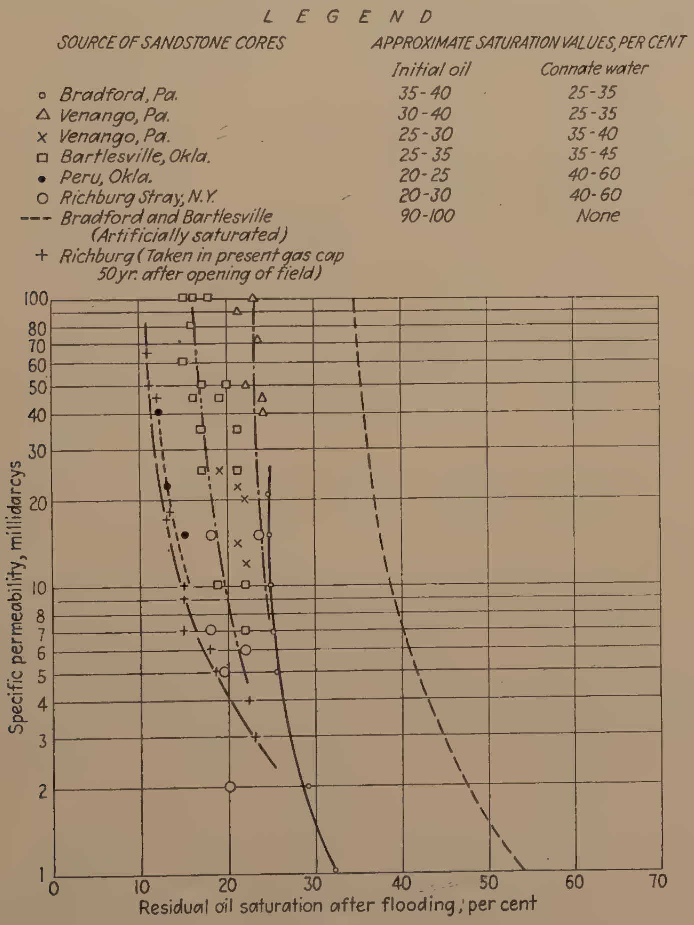

FIG. 7.

In Fig. 7 the results of a few laboratory flooding tests on sandstone cores of several productive formations are shown to indicate the general effect of connate-water saturation on the residual oil saturation remaining in the core after being subjected to laboratory water-flooding tests under comparable conditions. For conducting these tests samples of rotary cores were taken from sections of formation having rather uniform sand characteristics adjacent to the usual saturation samples. The samples for the flooding tests were prepared in the form of cylinders and subjected to flooding in the direction parallel to the bedding planes. Pressure gradients of the order of 5 to 10 lb. per sq. in. per inch were employed for the flooding operation and the residual oil saturations shown in Fig. 7 represent the condition of the core when the water-oil ratio of the fluids being produced had reached a value of approximately 500.

A plot of the specific permeability versus the residual oil saturation after flooding gives curves that are somewhat similar in character to the curves for permeability versus connate-water saturation shown in Fig. 6. For sands of similar physical characteristics the residual oil saturation after flooding is less for water-wet sands containing high connate-water saturation. This difference is strikingly indicated in Fig. 7, by the difference in the residual oil saturation for artificially saturated cores having no connate-water saturation and for the cores containing natural saturation.

In general, Bartlesville sand cores show a much wider spread in residual oil saturation than Bradford sand cores. Bartlesville cores having lower connate-water saturation and higher initial oil saturation than those shown in Fig. 7 frequently give residual oil saturations as high as those shown for Bradford cores.

The initial oil saturation of the Peru sand cores shown in Fig. 7 were comparable to the residual oil saturation remaining in the Bradford cores after flooding; however, because these cores appeared to be water-wet and contained more connate water, an appreciable amount of the oil present was recovered by laboratory water-flooding operations.

The flooding of the Peru and Richburg Stray sand cores brought out another item of possible significance. The Richburg Stray sand cores had initial oil saturations of from 20 to 30 per cent and contained a large amount of salt water. The formation produced mostly salt water with a little oil. The residual oil saturation of the cores was reduced only a small amount by flooding. The Richburg Stray sand cores appeared to be oil-wet, whereas the Peru sand cores appeared to be water-wet. The Richburg Stray sand in the area was very fossiliferous, had some calcareous cementing materials and contained considerable clayey matter. The Peru sand cores, on the other hand, were mostly silica with siliceous cementing materials.

The residual oil saturations of the Richburg sand shown in Fig. 7 were taken from the present gas cap of the formation some 50 years after the pool had been opened to production. Laboratory water-flooding tests failed to reduce the residual oil saturation of the cores. Cores taken from lower on the structure in the present oil-producing zone had higher oil saturation, and, although the physical characteristics of the sand were identical with those of the present gas cap, laboratory water-flooding tests yielded residual oil saturations similar to those shown for Bradford cores. While complete information is not available to definitely prove the contention, it seems possible that the effects of gravitational forces over the long period of time may have been sufficient to reduce the residual oil saturation of the zones of higher permeability to a much lower value than ordinarily is obtained in water-flooding operations.

The residual oil saturations obtained by laboratory flooding tests are influenced to some extent by the magnitude of the pressure gradient applied for flooding, by the viscosity of the oil, and by the physical characteristics of the sand. However, when the samples are selected to maintain these variables fairly constant, the pronounced effect of connate-water saturation on the residual oil saturation after flooding is clearly indicated. The supplementing of the usual core analyses by tests to indicate more directly the amount of recoverable oil in the formation greatly assists in the estimation of reserves and recovery from primary as well as secondary operations.

permeability-saturation relationships for unconsolidated sands, involving the flow of oil-gas mixtures. The general treatment of the flow of heterogeneous fluids through porous media by Muskat and Meres,[3] based upon the experimental data of Wyckoff and Botset,[4] is the first treatise of its kind permitting the application of the developed theoretical considerations to a specific problem.

A large portion of the petroleum produced in Oklahoma is taken from the Wilcox sand which is productive in various localities at depths ranging, for the most part, from 4000 to 7200 ft. below the surface. Proper application of fluid-flow data to production practice in these pools would probably result in an increase of ultimate recovery beyond present estimates and would serve as a basis upon which the development of new pools could be predicated. To this end, the present scope of this investigation has been confined to the flow of reservoir fluids through tubes packed with Wilcox sand.

APPARATUS AND MATERIALS USED

Mechanical Apparatus.—The apparatus used to obtain the data presented here consisted, essentially, of a flow tube 2 in. by 21 ft. 4 in., which was equipped with five pressure taps for Bourdon pressure gauges spaced at 5-ft. intervals and packed with unconsolidated Wilcox sand from the Oklahoma City reservoir, mounted on beam scales weighing to 0.05 lb.; a 1-gal. Wolff bottle, fitted up for use as an oil-gas separator, mounted on beam scales weighing to 0.01 lb.; and a domestic type of gas meter in a tin case, for measuring gas volumes to 0.01 cu. ft. Flexible connections were provided for both flow tube and separator, in order to obtain accurate weight measurements. The arrangement of the equipment and the manner of connecting it to the high-pressure separator at the well is illustrated in Figs. 1 and 2.

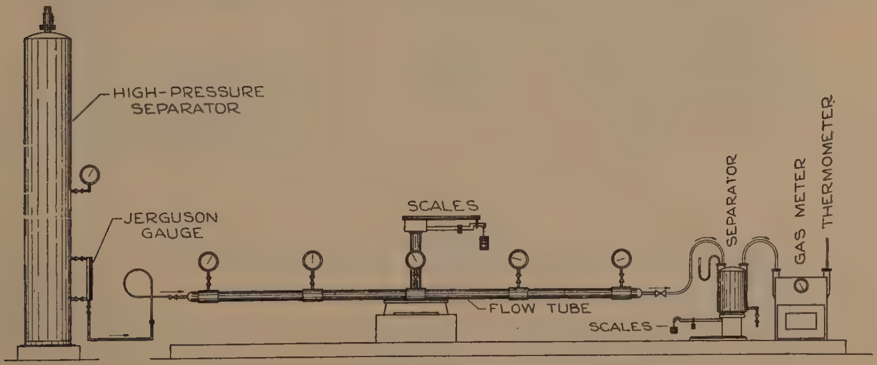

FIG. 1.—FLOW DIAGRAM OF TUBE ASSEMBLY.

Gas-saturated Crude Oil.—The gas-saturated oil used in this investigation was obtained, as shown, at the Anderson-Prichard Oil Corporation

No. 1 State well, in the Moore field, Cleveland County, Oklahoma. This oil is similar in many respects to the average Mid-Continent light crude oil, having an average gravity of 42° A.P.I. at atmospheric pressure.

Reservoir Sand.—Many of the studies of fluid flow through porous media have utilized carefully sized sand, or glass beads, in order to obtain interstices of uniform size and to make all pore space available for fluid flow. In this study, no attempt was made to obtain a sand body composed of uniformly sized sand grains, as it was desired to approximate natural reservoir conditions as closely as possible.

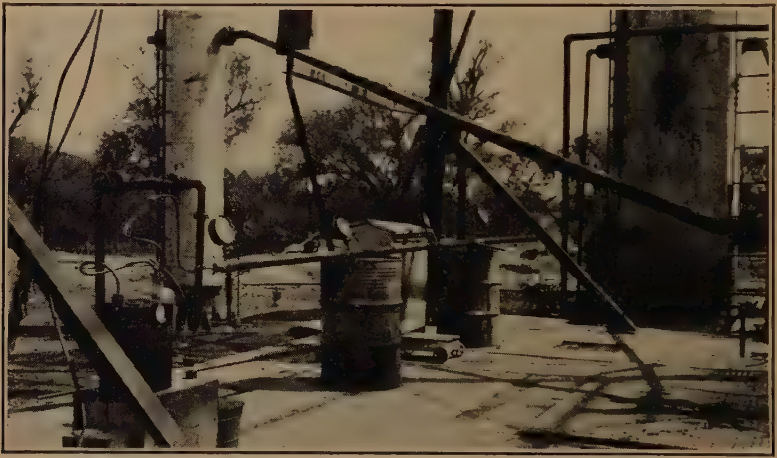

FIG. 2.—FLOW-TUBE ASSEMBLY, MOORE FIELD, OKLAHOMA.

A sieve analysis of this sand is as follows:

Retained on	Per Cent by Weight	Retained on	Per Cent by Weight
Mesh (Tyler)		100	57.90
24	0.92	150	18.68
35	0.70	200	5.10
50	1.80	Pan	1.00
65	13.90		
			100.00

Microscopic examination of clean Wilcox sand showed a well rounded, frosted, quartz grain; well suited to an investigation of this type.

Packing the Sand in Tube.—Reservoir sand, obtained from a cleanout of a well producing from the Wilcox zone in the Oklahoma City field, was selected for use in the tube instead of clean Wilcox outcrop sand. Preliminary investigations showed that the inherent asphaltene coating of the sand grains contributed a major portion of the resistance to fluid flow through the sand body. Obviously, the manner of packing the tube was of prime importance in order to obtain, as nearly as possible, constant porosity and permeability throughout the reservoir. This was accomplished by: (1) gluing a thin film of outcrop sand to the tube wall to ensure a perfect bond between the sand body and the walls, and (2) adding the reservoir sand in small amounts and packing it by simultaneous hammering on the tube walls and tamping with a length of ½-in. pipe. The sand was confined to a constant volume by means of 100-mesh Monel screen disks at the inlet and outlet ports, and by porous lead wool plugs at the pressure taps.

Porosity determinations were complicated by the fact that the weight of the reservoir sand was partly due to its residual oil content. To determine the weight due to the sand alone, an analysis was run by means of firing a weighed sand sample in a porcelain crucible for 3 hr. and noting the loss in weight, which was attributed to the residual oil in the sand. This method of analysis is based on the fact that Wilcox sand is practically pure silica and therefore is unaffected by temperatures below the fusion point.

Knowing the tube volume and the sand weight, together with the correction factor for residual oil content, the absolute porosity of the tube was calculated to be 34.3 per cent.

TEST PROCEDURE

As shown in Fig. 1, the tube inlet was connected to the bleeder valve at the bottom of the Jerguson gauge column on the high-pressure sepa-

TABLE 1.—*Steady-state Flow through 2-in. Tube*

Air temperature, 95° F. Barometric pressure, 14.1 lb. per sq. in. abs.

Run No.	1	2	3	4	5	6	7
Pressure, lb. per sq. in. abs.							
Saturation	604	574	581	584	586	577	570
1st tap	594	564	571	574	576	567	560
2nd tap	476	471	492	520	496	473	451
3rd tap	379	400	438	484	443	396	360
4th tap	239	299	363	437	368	299	229
5th tap	114	214	312	415	312	214	114
Relative density of oil-gas mixture in tube vs. water	0.570	0.583	0.588	0.599	0.577	0.566	0.566
Residual oil run, lb	2	2	2	2	2	2	1
Residual oil gravity, deg. A.P.I.	41.9	41.8	41.9	41.8	42.2	42.2	41.9
Metered gas, cu. ft	4.46	4.25	4.25	4.14	4.18	4.33	2.25
Produced gas, std. cu. ft	4.02	3.79	3.78	3.68	3.74	3.865	2.00
Total time, sec	467	574	759	1191	757	591	252
Residual oil rate, gal. per min	0.0370	0.0306	0.0232	0.0148	0.0235	0.0300	0.0349
Gas rate, cu. ft. per min	0.5060	0.3960	0.2990	0.1850	0.2970	0.3925	0.4770
Gas-oil ratio	574	542	540	526	533	548	574

rator. In flowing oil to the tube, the valve between the top of the gauge column and the separator was closed to prevent gas from entering the flow tube. Saturation of the sand body was accomplished by opening both inlet and outlet valves, permitting gas-saturated oil to flow through the tube until all dead oil had been displaced. The outlet valve was then closed, gradually, until maximum readings of tube weight and over-all pressure were obtained. This procedure required from 30 to 45 minutes.

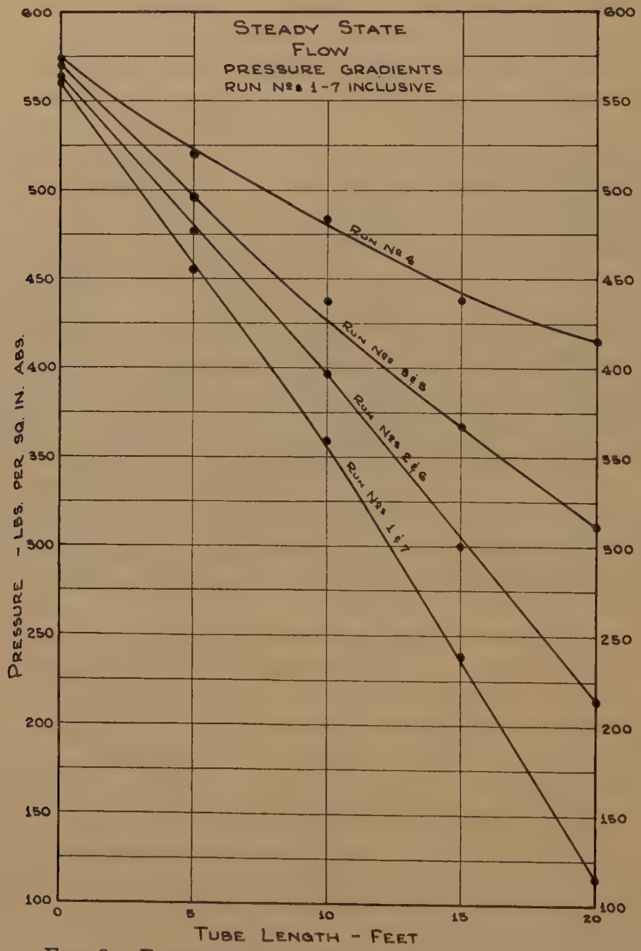

FIG. 3.—PRESSURE GRADIENTS, STEADY-STATE FLOW.

Steady-state Flow.—Tube regulation for steady-state flow tests was maintained by opening the tube inlet valve to the high-pressure separator and adjusting the outlet valve so as to set the fifth tap pressure at a predetermined value. When a steady-state condition had been reached, data were taken, based on the flow of one pound of residual oil into the separator. Time of flow and gas-meter readings were observed on the swing of the scale beam at the start and finish, by means of a stop watch. The gas temperature was taken at the meter outlet, and the residual oil gravity determined by a standard A.P.I. hydrometer.

Unsteady-state Flow.—In carrying out unsteady-state flow tests, great care was exercised to completely saturate the tube with fresh gas-saturated oil, as described above. When both weight and pressure readings were observed to be constant, the inlet and outlet valves were closed and all initial readings noted. The outlet valve was then opened to a predetermined position and readings taken for pressures at all taps, residual oil weight, and gas-metered for the first two ½-min. intervals and at each minute thereafter until the efflux of residual oil from the tube had declined to the point where successive weight increments were practically negligible.

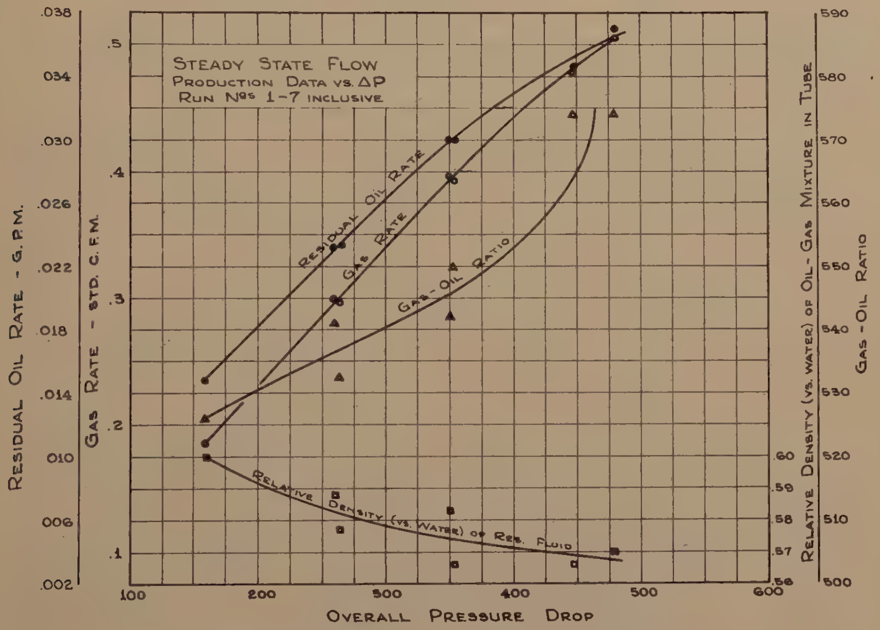

Fig. 4.—Rates of oil and gas production, steady-state flow.

Discussion of Results

Steady-state Flow

Pressure Differentials.—The original data are presented in Table 1. The distribution of pressure throughout the tube is shown in Fig. 3. For the lower over-all pressure differentials there is a tendency for the pressure to fall off more slowly as the outlet end of the tube is approached, while for the higher over-all differentials the rate at which the pressure falls increases toward the discharge end. With the release of gas from solution in the crude oil, it was expected that the resistance to the flow of the two-phase mixture would increase progressively but, for some unknown cause, this increase in resistance was not evident until the over-all pressure drop was increased to 300 lb. per sq. in. throughout the length of the tube. No doubt the higher differential pressures caused an increased evolution of gas with a resultant greater resistance to flow toward the outlet end of the tube. This explanation is supported by the theory of effective permeability of gas-liquid mixtures as proposed by Wyckoff and Botset,[4] who stated that the greater the gas-oil ratio at any point within the tube, the lower would be the effective liquid permeability and, therefore, the greater the differential pressure required to maintain steady-state flow.

TABLE 2.—*Unsteady-state Flow through 2-in. Tube*

RUN NO. 8. VALVE SETTING, ⅛ ROUND OPEN

Air temperature, 94° F.	Residual oil gravity, 40.8° A.P.I.
Gas temperature, 98° F.	Weight of charged oil, 6.64 lb.
Barometric pressure, 14.1 lb. per sq. in. abs.	Saturation pressure, 551 lb. per sq. in. abs.

Cumulative Time, Min.	Average Tube Pressure, Lb. per Sq. In. Abs.	Tube Weight Loss, Lb.	Produced Gas Volume, Cu. Ft.	Corrected Gas Volume, Cu. Ft.	Residual Oil Weight, Lb.	Residual Oil Rate, Gal. per Min.	Gas Rate, Cu. Ft. per Min.	Gas-Oil Ratio	Cumulative Residual Oil, Gal.	Cumulative Prod. Gas, Cu. Ft.	Cumulative Oil and Gas Recovery, Wt. Per Cent
0	541	0	0	0	0	0	0	0	0	0	0
½	467	0.50	0.57	0.522	0.30	0.08760	1.044	500	0.0439	0.522	7.52
1	443	0.40	0.54	0.494	0.37	0.10820	0.988	415	0.0980	1.016	13.54
2	409	0.50	0.79	0.723	0.40	0.05850	0.723	519	0.1560	1.739	21.10
3	360	0.30	0.79	0.723	0.12	0.01753	0.723	1734	0.1740	2.462	25.60
4	317	0.00	0.71	0.650	0.10	0.01460	0.650	1868	0.1890	3.112	25.60
5	278	0.20	0.58	0.531	0.07	0.01020	0.531	2180	0.1990	3.643	28.65
6	247	0.00	0.55	0.503	0.06	0.00877	0.503	2415	0.2080	4.146	28.65
7	220	0.10	0.54	0.494	0.05	0.00731	0.494	2840	0.2150	4.640	30.10
8	193	0.10	0.43	0.393	0.03	0.00438	0.393	3770	0.2190	5.033	31.60
9		0.00	0.42	0.384	0.04	0.00585	0.384	2760	0.2250	5.417	31.60
10	151	0.20	0.36	0.330	0.03	0.00438	0.330	3165	0.2300	5.747	34.60
11		0.00	0.33	0.302	0.02	0.00292	0.302	4340	0.2330	6.049	34.60
12	120	0.10	0.32	0.293	0.02	0.00292	0.293	4210	0.2350	6.342	36.10
13		0.00	0.27	0.247	0.01	0.00146	0.247	7100	0.2370	6.598	36.10
14	102	0.00	0.24	0.220	0.01	0.00146	0.220	6300	0.2380	6.809	36.10
15		0.00	0.21	0.193	0.01	0.00146	0.193	5530	0.2395	7.001	36.10
16	81	0.10	0.21	0.193	0.01	0.00146	0.193	5530	0.2410	7.194	37.60
17		0.00	0.23	0.211	0.00	0.00000	0.211		0.2410	7.405	37.60
18	70	0.00	0.11	0.101	0.00	0.00000	0.101		0.2410	7.505	37.60
Over-all.....		2.50	8.20	7.507	1.65			1425	0.2410	7.505	37.60

Production Rates.—In Fig. 4, the relationship is shown between production rates and the over-all pressure drop across the tube. Both the oil and gas rates vary directly with the pressure differentials through the tube until the outlet pressure reaches about one-half of the saturation pressure, after which the oil and gas rates begin to level off. Muskat and Meres[4] have shown, in a theoretical analysis, that the performance of a heterogeneous fluid under steady-state flow is similar in character to the behavior of the oil-gas mixture presented in Fig. 4. The relative over-all density of the oil-gas mixture versus water varied from 0.600 to 0.566, depending upon the pressure drop.

Unsteady-state Flow

Pressure Gradients.—The original data for the unsteady-state flows are presented in Tables 2 and 3. The two runs were made at different rates by setting the efflux valve at small and at relatively large openings. The pressure gradients are presented in Figs. 5 and 6, showing pressure distribution through the reservoir at various time intervals. Run No. 8 is typical of a relatively slow efflux rate. In the early part of the run the over-all pressure drop was 165 lb. per sq. in., while at the end of the same run the differential had fallen to 27 lb. per sq. in. In the fast run (run No. 9), the differential, after ½ min., was 265 lb. per sq. in. However, at the end of the run, it had declined to approximately 30 lb. per sq. in. Muskat and Meres[3] have also analyzed the history of the pressure decline in a linear channel with one terminal closed and the other open

TABLE 3.—*Unsteady-state Flow through 2-in. Tube*

RUN NO. 9. VALVE SETTING ¼ ROUND OPEN

Air temperature, 94° F.	Residual oil gravity, 41.0° A.P.I.
Gas temperature, 102° F.	Weight of charged oil, 6.74 lb.
Barometric pressure, 14.1 lb. per sq. in. abs.	Saturation pressure, 568 lb. per sq. in. abs.

Cumulative Time, Min.	Average Tube Pressure, Lb. per Sq. In. Abs.	Tube Weight Loss, Lb.	Produced Gas Volume, Cu. Ft.	Corrected Gas Volume, Cu. Ft.	Residual Oil Weight, Lb.	Residual Oil Rate, Gal. per Min.	Gas Rate, Cu. Ft. per Min.	Gas-Oil Ratio	Cumulative Residual Oil, Gal.	Cumulative Prod. Gas, Cu. Ft.	Cumulative Oil and Gas Recovery, Wt. Per Cent
0	558	0	0	0	0	0	0	0	0	0	0
½	422	0.80	1.15	1.040						1.040	11.86
1	381	0.60	0.67	0.605	1.04	0.15200	1.645	454	0.152	1.645	20.75
2	330	0.25	1.36	1.230	0.37	0.05410	1.230	954	0.206	2.875	24.50
3	261	0.35	1.23	1.110	0.22	0.03220	1.110	1447	0.238	3.985	29.70
4	203	0.30	1.18	1.067	0.07	0.01020	1.067	4390	0.249	5.052	34.20
5	155	0.15	0.92	0.832	0.06	0.00876	0.832	3990	0.257	5.884	36.40
6	123	0.05	0.64	0.577	0.03	0.00438	0.577	5520	0.261	6.461	37.10
7	99	0.05	0.51	0.460	0.01	0.00146	0.460	13260	0.263	6.921	37.80
10	64	0.10	0.97	0.877	0.03	0.00146	0.292	8390	0.268	7.798	39.30
18	34	0.15	1.13	1.020	0.06	0.00110	0.128	4865	0.276	8.818	41.50
Over-all.....		2.80	9.78	8.83	1.89			1335	0.276	8.818	41.50

to production, resulting in pressure-gradient curves similar in character to those presented here.

Production Rates.—The graphical analysis of run No. 8 is given in Fig. 7, showing the production rates of oil and gas in their relationship to time. These rate curves take the usual shape of reservoir depletion curves, with a tendency for the gas-oil ratio to increase gradually throughout the production period. In the faster run (Fig. 8), the decline of the oil rate is much sharper. Toward the close of this period of rapid decline, the gas-oil ratio goes through a maximum, due in part to the pronounced flattening of the oil-rate curve, together with the steady decline in gas rate.

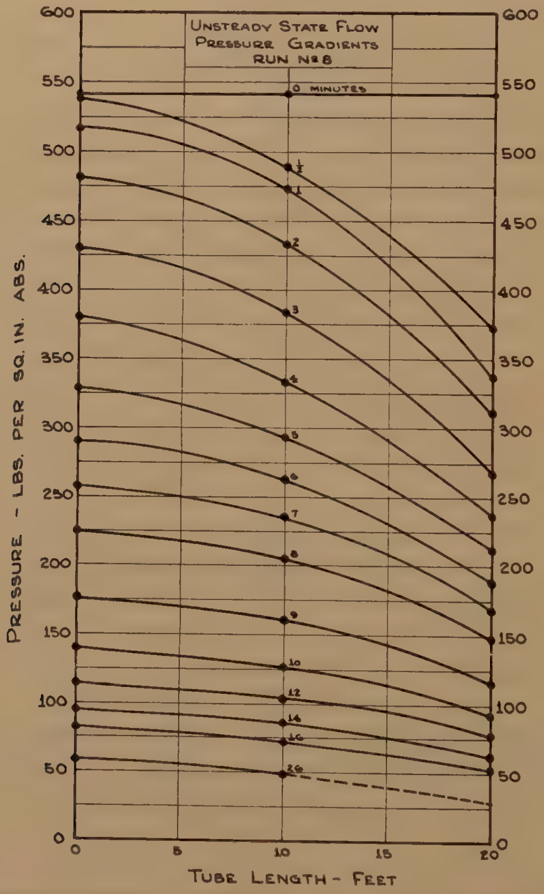

FIG. 5.—PRESSURE GRADIENTS, UNSTEADY-STATE FLOW (RELATIVELY SLOW RATE).

In Figs. 9 and 10, the cumulative production records are plotted against the average reservoir pressures existing at various time intervals. It is interesting to observe that the maximum production of oil per unit reservoir-pressure decline comes in the early life of the cycle. In this connection it should be noted that, in saturating the sand in the tube prior to commencing these tests, the initial reservoir fluid content attained ranged from 96 to 98 per cent by weight; indicating the presence of some free gas.

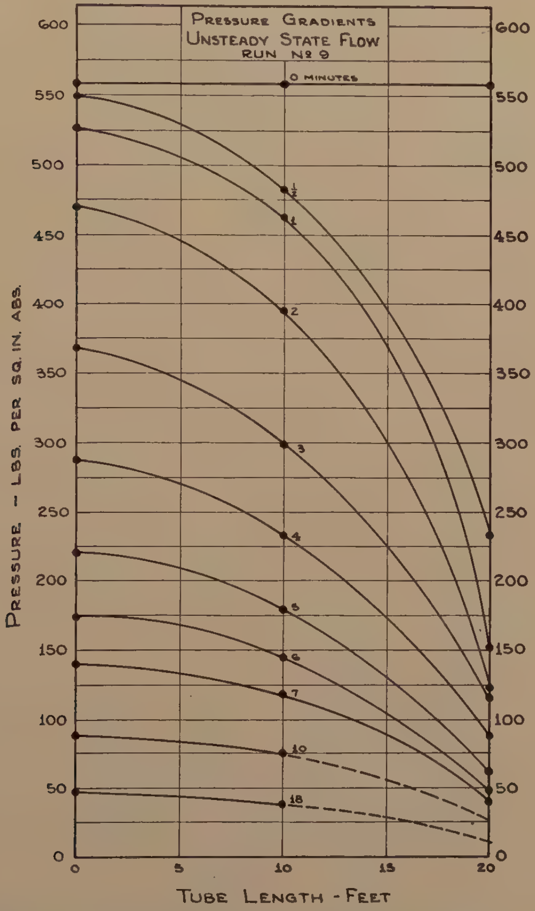

FIG. 6.—PRESSURE GRADIENTS, UNSTEADY-STATE FLOW (RELATIVELY FAST RATE).

Therefore it is evident that this maximum production per unit of pressure decline is the result of the expansion of the free gas[2] and that subsequent production is due to the relatively slow diffusion of solution gas into the gas cap, as evidenced by the decreased slope of the curve.

CONCLUSIONS

To summarize the results of the data presented here, the following conclusions may be drawn:

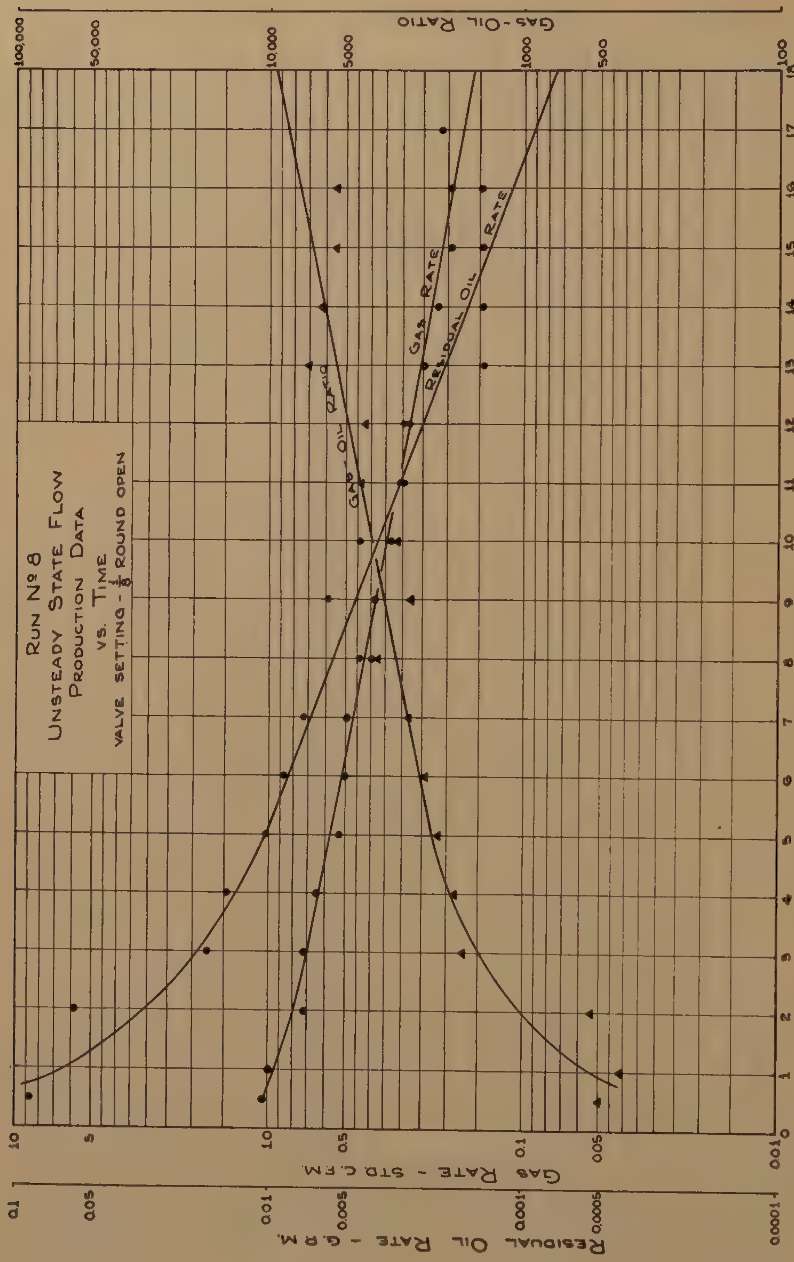

FIG. 7.—RATES OF OIL AND GAS PRODUCTION, UNSTEADY-STATE FLOW (SLOW).

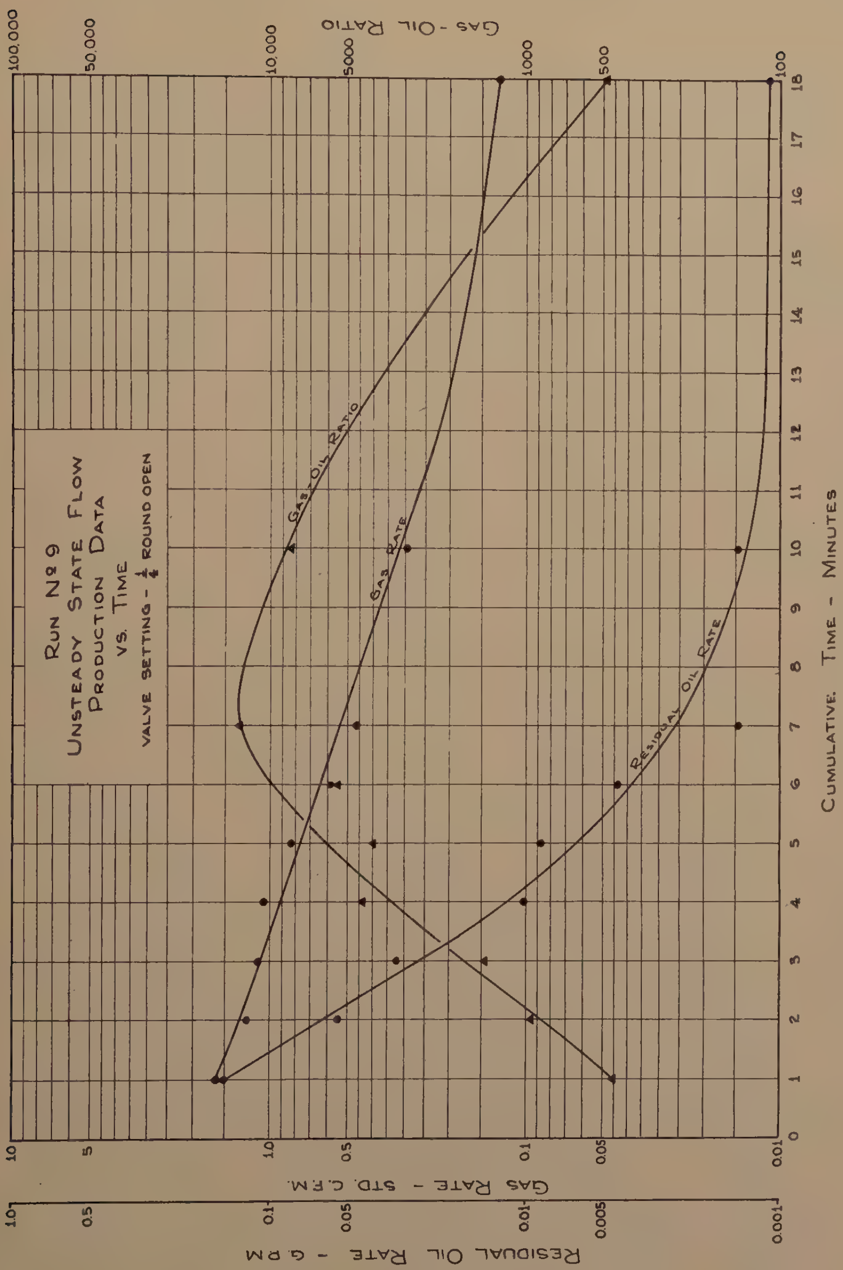

FIG. 8.—RATES OF OIL AND GAS PRODUCTION, UNSTEADY-STATE FLOW (FAST).

1. Pressure gradients observed when maintaining both steady-state and unsteady-state flow of an oil-gas mixture through an unconsolidated sand body very closely approximate the gradients obtained experimentally from a carbon dioxide-water system by Wyckoff and Botset[4] and the theoretical consideration developed by Muskat and Meres.[3] The shape of these curves plainly demonstrates the importance of effective permeability in heterogeneous fluid flow through porous media.

2. Further analysis of these data indicates that, in order to obtain the maximum degree of flow efficiency and to maintain minimum gas-oil ratios in the reservoir, the flowing bottom-hole pressure should be equal to at least 50 per cent of the shut-in bottom-hole (or saturation) pressure.

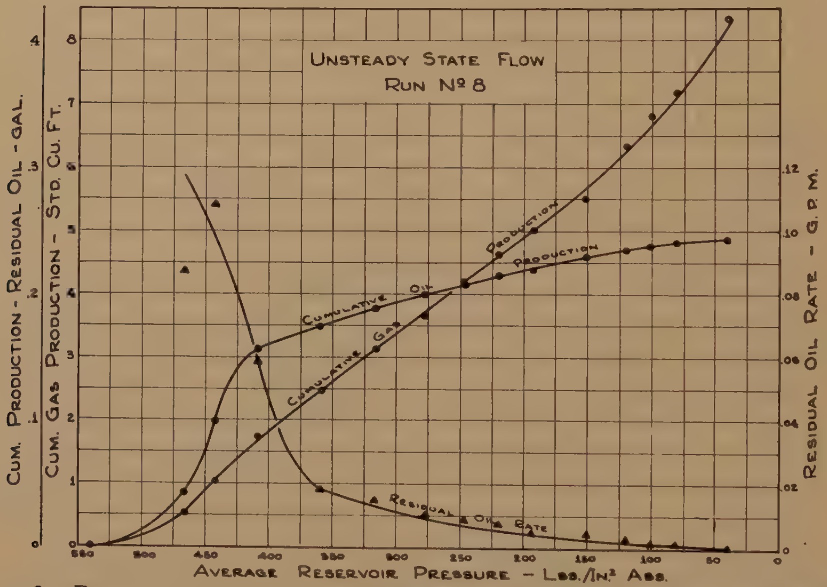

FIG. 9.—PRODUCTION VERSUS AVERAGE RESERVOIR PRESSURE FOR UNSTEADY-STATE FLOW.

3. The productive history of the reservoir under various conditions of unsteady-state flow shows a rather remarkable similarity to that obtained in actual practice. The effect of the presence of a gas cap on oil production is shown, and also the variation in decline of oil and gas rates and gas-oil ratio trends for different rates of withdrawal.

4. Data obtained from these various conditions of unsteady-state flow suggest that the ultimate yield of oil and gas is some function of the rate of withdrawal from the reservoir. The existence of an optimum rate of withdrawal has been indicated, since the ultimate recovery may be reduced by producing the reservoir at a very low rate, as well as at a very high rate.

ACKNOWLEDGMENT

The authors wish to express their appreciation to the Anderson-Prichard Oil Corporation for permission to carry out the experimental work on that company's State lease in the Moore field, Cleveland County, Oklahoma.

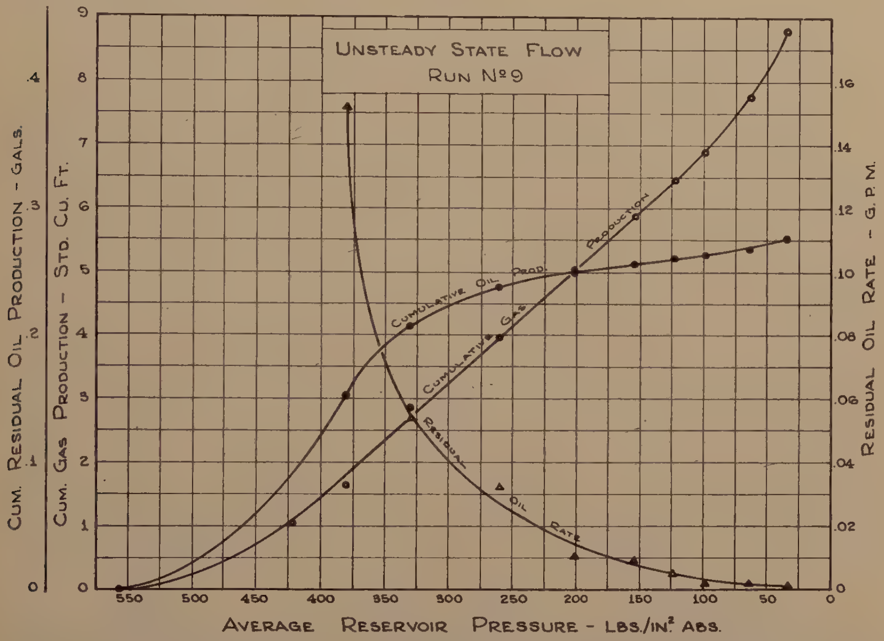

FIG. 10.—PRODUCTION VERSUS AVERAGE RESERVOIR PRESSURE FOR UNSTEADY-STATE FLOW.

Messrs. G. O. Kimmell, Marvin Owens, Jr., A. K. Korn and H. M. Black assisted in the construction and operation of the experimental apparatus.

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Recent Advances in Knowledge of the Colloidal Properties of Clay Suspensions and Gels

By Charles E. Reed*

(Oklahoma City Meeting, October, 1937)

With the increasing importance of clay in drilling operations which demand more precise and exacting control over its behavior, there has come the realization that most of our present methods of control over many of its important properties still represent more of an art than a science. Such a situation with respect to a material of such industrial significance is unfortunate, and naturally many investigations have been conducted to improve our knowledge. In general, these investigations have revealed the complex nature of clay behavior and while sometimes they may not have seemed to contribute directly to a solution of the field operator's problems they have been of inestimable importance in bringing to light the broad fundamental scientific principles upon which must be based any effective working theory correlating the known facts of clay behavior and predicting profitable new lines of attack for its improvement.

Major Facts Concerning Behavior of Clays

In the study of clays, as in that of most other colloidal materials, it has been impossible to make progress by the study of isolated facts. On the other hand, analysis of large groups of facts, many of which seem at first completely unrelated, can lead to a deeper insight into the structure of clays and the mechanism of their behavior. It will be well to list the major facts on which the analysis here presented is based, starting with those that have emerged repeatedly from past investigations and which thereby constitute an impregnable foundation upon which must rest any comprehensive theory of clay behavior:

1. Clays consist of hydrated aluminosilicates of extremely fine and variable particle size.

2. Suspended in water, clays exhibit variable degrees of swelling, depending upon their origin and upon the chemical and colloidal nature of any other substances present. The magnitude of the swelling is a direct indication of the extent to which the clay has become dispersed.

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3. Associated with any given natural clay is always found a definite quantity of dissociable metals, usually alkaline or alkaline-earth cations. These cations are readily replaceable by each other and by hydrogen; a clay may be saturated with any metallic cation by repeated treatment with a solution of the corresponding neutral salt or hydroxide in the case of a metal, or acid in the case of hydrogen.

4. Purification of clay from replaceable metals may be effected by dialysis. In this process the water dispersion of clay is enclosed within a membrane having pores large enough to allow free passage of the ions across it to distilled water without, where they are washed away. The clay particles are too large to pass through the pores of the membrane and they remain behind where hydrogen ions from the water replace the cations that have been removed.

5. The viscosity of clay suspensions is always markedly greater than that of water alone and, like swelling, varies widely with the chemical and colloidal nature of any other substances present. This increased viscosity must be due to the interference of the suspended particles of clay with normal flow of the suspending liquid.

6. Under proper, but widely variable, conditions of concentration of clay and electrolyte present it is possible to obtain a clay gel that possesses a yield point necessitating a finite distorting force to make it flow as contrasted to a suspension which, like a true liquid, will flow under a differential distorting force.

7. Examined under the ultramicroscope the individual clay particles in a fluid suspension (sol) exhibit violent Brownian motion, while those in a gel are still distinct, but motionless. Without question the formation of a gel with its yield point and greatly increased viscosity has come from some type of structure built up within the liquid as a result of the suspended particles becoming locked into fixed positions, although, as will be seen later, the mechanism by which this locking takes place is questionable.*

8. Very often the particles are locked into place only loosely, as it is possible by relatively weak mechanical agitation to destroy the gel structure and produce a sol, which, if allowed to stand undisturbed, will increase in viscosity and reset to a gel. Such systems are called thixotropic in the literature.

9. The viscosity of a clay suspension is a much more complex quantity than that of a true liquid, where it is a constant equal to the shearing

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* The occurrence of structure in a suspension of particles implies that a finite force is necessary to change the position of any one particle with respect to the other particles. Under such conditions the suspension of particles is said to constitute a gel as contrasted to a sol, a suspension in which each particle may be freely moved about by application of only a differential distorting force. Many types of structure may be imagined to exist within a gel and gels of different substances may have widely differing types of structure.

stress divided by the rate of shear. If, by analogy to a liquid, the viscosity of a suspension be defined as the ratio of shearing stress to rate of shear, this quantity is not a constant but is some complex function not only of the rate of shear itself but also of the time and the past history of the suspension, the latter manifesting itself as thixotropic behavior. Therefore, whenever viscosities of clay suspensions are reported they are meaningless unless accompanied by a detailed description of the exact conditions of measurement.

Relevant Facts from Recent Investigations

It must be repeatedly emphasized that the only difference between clay suspensions and gels that has been discovered to date is a mechanical difference, the gel possessing a yield point and a higher viscosity. From the standpoint of the production engineer, it is just these mechanical differences that are most vital, for they must affect directly such important properties of a drilling mud as its ability to suspend and be freed from cuttings, its ease of circulation and settling characteristics, and its retention of gas bubbles. As the relatively high viscosity of clay sols is due to interference of the constituent particles with flow and as the yield point of clay gels is due to these same particles forming a structure it is clear that particle structure, shape and size will exert a tremendous influence upon all of the important mechanical properties mentioned above. Our knowledge of all these properties, formerly highly speculative, has undergone great strides as a result of recent investigations.

Particle Structure and Shape

Clays of industrial importance may be divided into two main groups—the kaolinite group having the empirical formula $Al_2O_3.2SiO_2.2H_2O$ and the montmorillonite group the empirical formula $Al_2O_3.4SiO_2.H_2O$. It has been shown from X-ray data that the crystal lattice of both groups is of the layer type consisting of superimposed planes of aluminum and silicon bound together through oxygen bridges.[13]

Fig. 1 shows a schematic diagram of the structure of montmorillonite, the chief clay mineral in bentonite.[8,9] Each group of planes consisting of two layers of silicon atoms bound to one layer of aluminum atoms through planes of oxygen atoms can extend indefinitely in the *b* direction as shown on the diagram and in the *a* direction perpendicular to the diagram. Such a group of planes, hereafter referred to as a crystallite, is composed of an indefinite number of unit cells—the smallest units in the crystal that repeat themselves. The clay particle may consist of but one crystallite or an indefinite number of crystallites stacked on top of each other like a pack of cards and held together by residual surface forces. The structure shown in Fig. 1 indicates that individual clay particles have great strength and that they might readily form the rigid, platelike particles with enormous ratios of length to thickness as previously postulated.[19,11]

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[13] References are at the end of the paper.

Fig. 1 also illustrates that the clay minerals are in general of widely variable compositions and isomorphous structure, it being possible in this case for iron and magnesium to replace aluminum.

An insight into the origin of the swelling properties of bentonite muds may be obtained by examination of Figs. 1 and 2. When bentonite is dry the individual crystallites are bound closely to one another and the distance in the *c* direction from any plane in one crystallite to the corresponding plane in an adjacent crystallite is about 11 Å. (1 Å. = 10^{-8} cm.). When water is added to the bentonite in increasing amounts, the water molecules migrate in between adjacent crystallites and pry them farther and farther apart.

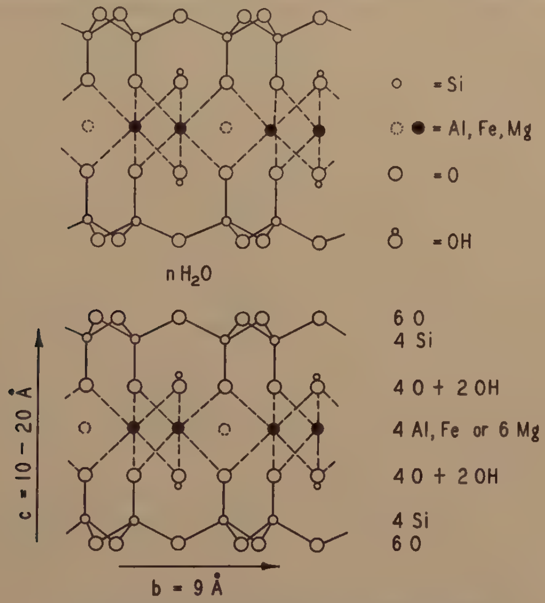

FIG. 1.—SCHEMATIC DIAGRAM OF MONTMORILLONITE.
$[H_2O(Al_2O_3.Fe_2O_3.3MgO)4SiO_2 + nH_2O]$

Hofman and Bilke have watched this process take place under the X-ray and have measured how the distance between corresponding atoms in adjacent crystallites increases with water content of the clay. Fig. 3 shows that as the vapor pressure of H_2O over the clay increases from 0 to 17 mm. Hg, corresponding to an increase in water content from 0 to 37 per cent, this distance practically doubles. At higher water concentrations it is possible that some of these groups of planes become quite free from their neighbors and float off through the suspension.

Before leaving Fig. 1, attention should be called to the probable location of metallic cations and hydrogen in bentonite. It can be seen that if a water molecule should react with an oxygen atom bound to two silicon atoms in the surface plane of a crystallite, two hydroxyl groups would result. The hydrogen of these hydroxyls can ionize and be replaced by metals, and in strongly acid solutions the hydroxyl group as a whole can react as a base giving clay its amphoteric properties. In addition, it is possible that there is enough room in the crystal lattice for the dissociable hydrogen ions to migrate out from the interior hydroxyl groups into solution. The dissociation of cations in the form of hydrogen or metals from the clay particle leaves it with its characteristic negative change, and indeed it is possible to think of clay as a polyvalent electrolyte with a

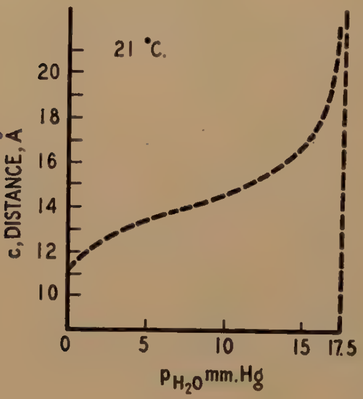

Fig. 2.

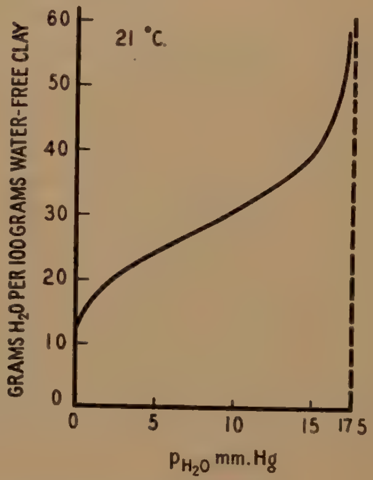

Fig. 3.

Fig. 2.—Swelling of Na montmorillonite.
Fig. 3.—Water content of Na montmorillonite.

large colloidal anion. The dissociable ions have a definite, average, standoff distance from the surface of the particle, this distance being determined by an equilibrium between the forces of kinetic activity tending to move them out into solution and the forces of electrostatic attraction tending to restrain them within the vicinity of the surface. Since the attraction between two electric charges of opposite sign is proportional to the product of the charges and inversely proportional to the distance between them, the average standoff distance of divalent and polyvalent cations from the surface of a crystallite is less than that of univalent cations.

Hydrogen bentonite prepared either by acid washing or dialysis may be titrated to an end point with base and its equivalent weight determined as around 1000.[5,18] The fact that the equivalent weight of a bentonite of a given origin is a constant independent of the size of the individual particles[5] is additional evidence for the open, porous structure of the clay particle as presented in Fig. 1, indicating that ions can migrate into the cracks between crystallites. Fig. 1 indicates, however, that if the lattice were to be broken up a change in equivalent weight of the clay could occur in some cases, depending on the state of aggregation of the plates. This result has been reported for some clays.[20]

It is the unusual swelling ability of bentonite that makes it so valuable as a suspending and geling agent. Kaolin, while having a layer lattice similar in some respects to bentonite, does not exhibit the variable *C* distance between its groups of planes and, as is well known, kaolin swells in water to an order of magnitude less than that of bentonite. Many muds with intermediate swelling properties may consist of mixtures of minerals of the kaolinite and montmorillonite type and the blending of such types suggests a possible method of control over the mechanical properties of the resulting suspensions and gels.

Most of the particles of kaolins are large enough to be seen under the ordinary microscope and their tendency to assume the platelike habit is unmistakable. On the other hand, the majority of the particles in bentonite are too small to be resolved under the ordinary microscope but when viewed in the ultramicroscope they can be seen indirectly as innumerable twinkles and flashes of light resulting from the changing intensity of light reflected from the faces of tiny plates twisting and turning in ceaseless Brownian motion.

PARTICLE SIZE AND ITS DISTRIBUTION

All naturally occurring clays contain particles of different sizes. In kaolins it is usually found that 90 per cent of the particles have dimensions greater than 500 mμ (1 mμ = 10^{-7} cm.) and hence can be measured directly in the ordinary microscope. In contrast, most of the particles in bentonite cannot be resolved in the ordinary microscope and indirect methods must be used to estimate the particle size.

The most convenient method of characterizing the size of small particles lies in a determination of their settling rates. A particle settling in a liquid will increase in velocity until the frictional drag exerted upon it is just equal to the force causing it to settle. In general, the greater the mass of a particle of given shape, the greater its settling velocity, while a particle of given mass will settle at different velocities, depending upon its shape. Although it is known that platelike particles of given mass settle more slowly than spherical particles of equal mass, the laws governing the sedimentation of plates are unknown and it has become customary to report a particle of any shape settling at a given rate as having an "equivalent diameter" equal to the diameter of a spherical shaped particle of the same material that will settle at the same rate. Since in general all particles of a given material are of similar shape, the concept of "equivalent spherical diameters" enables us to compare the relative size of particles.*

Since a sample of clay will, in general, contain particles of variable size, it is important to know the nature of the particle-size distribution; i.e., the proportions of the sample represented by particles of different

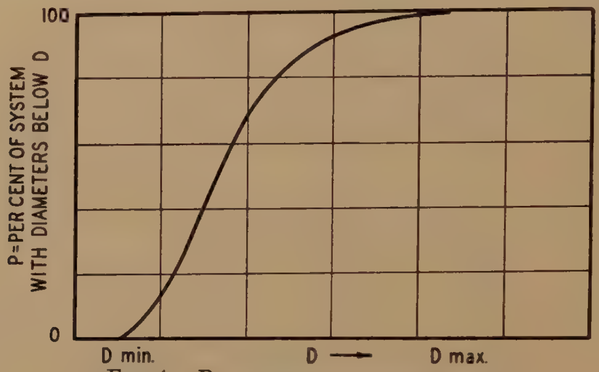

FIG. 4.—PARTICLE-SIZE DISTRIBUTION.

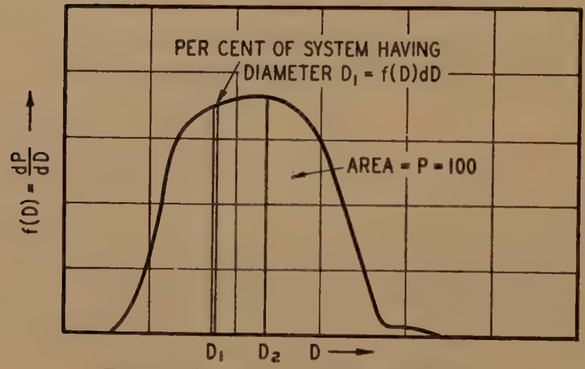

FIG. 5.—DATA OF FIG. 4 REPLOTTED.

sizes.† Particle-size distribution data may be obtained most conveniently by sedimentation methods. The particles in most clays are too small for practical separation by gravity and it is necessary to resort to centrifugal fields.*

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* An additional complicating factor in the interpretation of equivalent spherical diameters comes from the fact that the velocity of a particle may vary according to the position it occupies in settling. Thus, plates will settle fastest when their long axes are parallel to the direction of sedimentation. Fortunately, the complication of this factor is reduced to a minimum in the present case, where we are dealing with plates and all sedimentations were conducted in strong centrifugal fields. Under these circumstances a force analysis on a settling plate shows that it will orient with its long axes parallel to the direction of sedimentation. Thus all plates will settle in the same relative position.

† The particle-size distribution of a given sample may be represented by a curve like that in Fig. 4, where the ordinate P at any point gives the per cent by weight of the particles in the sample having diameters below D. Frequently the data represented by the type of curve in Fig. 4 are replotted in the form of Fig. 5. In Fig. 5,

Table 1 presents size-distribution data obtained by Marshall on a kaolin and a bentonite. The coarse impurities, those about 2μ (1μ = 0.001 mm.), were removed by gravity sedimentation. The clays were purified of metals by electrodialysis and suspended in 0.2 per cent Na_2CO_3.

TABLE 1.—*Size-distribution Data*

Clay	1μ	1μ–500 $m\mu$	500-200 $m\mu$	200–100 $m\mu$	100–50 $m\mu$	< 50 $m\mu$
Kaolin......	58.6[a]	30.1	7.5	3.8		
Bentonite...	14.6	19.5	20.6	4.0		39.3

[a] Per cent by weight of sample having equivalent spherical diameters > 1μ.

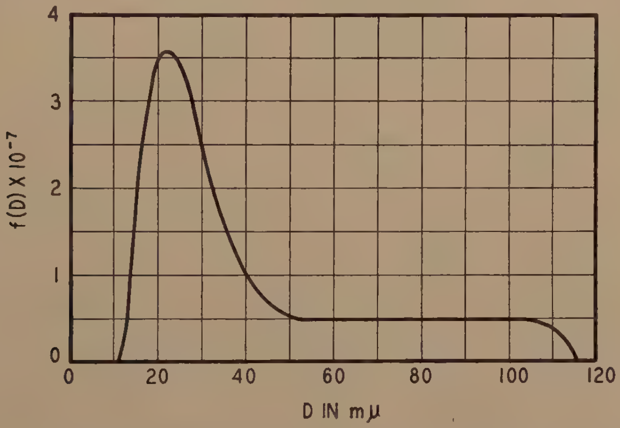

FIG. 6.—PARTICLE-SIZE DISTRIBUTION OF WYOMING BENTONITE.

The great difference between kaolin and bentonite is readily apparent. It is probable that the larger fractions of this bentonite are not homogeneous and that the true montmorillonite fraction with high swelling and geling properties is the finest material. Hauser and Reed have reported a complete centrifugal sedimentation analysis on a highly purified sample

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at any value of the diameter D, the corresponding ordinate is the slope of the curve in Fig. 4 at this same value of D. This slope is called the particle-size distribution function $f(D)$, and the ratio of the area bounded by any two ordinates in Fig. 5, such as D_1 and D_2, to the total area under the curve extending from the smallest to the largest particle is equal to the per cent by weight of the particles in the sample having diameters between D_1 and D_2.

* It is without the scope of this paper to describe centrifugal methods of particle size analysis. Marshall[14] has proposed a method using the basket-type centrifuge, which is applicable to the larger particles in clays, while Hauser and Reed[4] have developed a method using the supercentrifuge, which is applicable to the finest particles. While the ultracentrifugal methods of The Svedberg[17] would be applicable to clays, the expense and complication of the apparatus required has greatly limited their adoption.

of Wyoming bentonite, the particle-size distribution curve of which appears in Fig. 6. The chemical analysis of this bentonite approximates the formula $Al_2O_3.4SiO_2.H_2O$ and 75 per cent of the sample consists of particles with equivalent spherical diameters less than 50 mμ and a large fraction of the material below 50 mμ is relatively uniform in size.

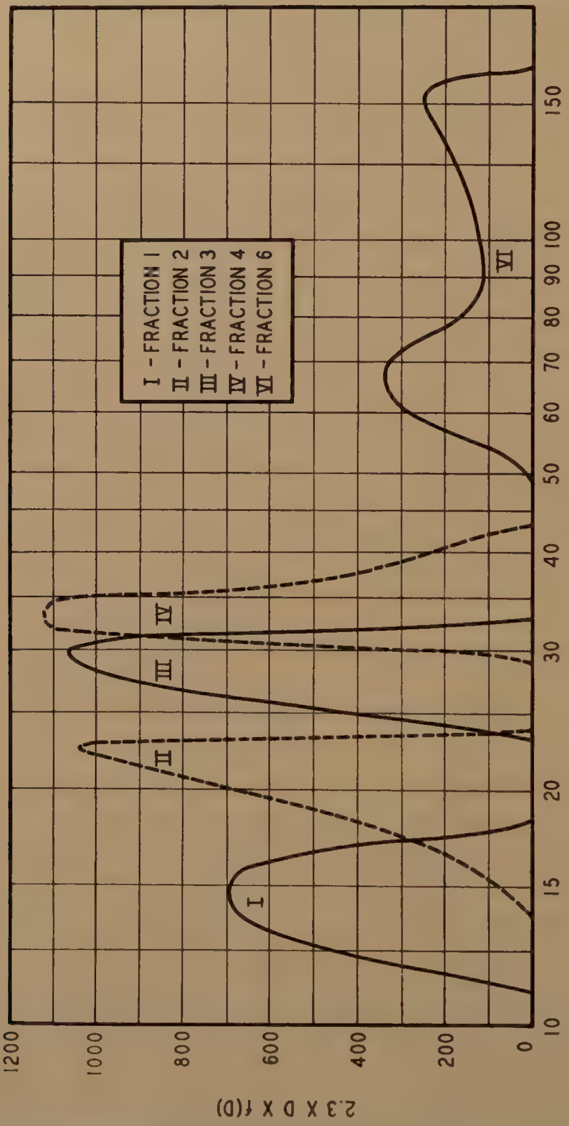

FIG. 7.—BENTONITE FRACTIONS OBTAINED BY CENTRIFUGAL FRACTIONATION.

EFFECT OF PARTICLE SIZE UPON COLLOIDALITY

In an attempt to establish the effect of particle size upon the colloidal properties of clay suspensions and gels, a sample of Wyoming bentonite was subjected to a series of centrifugal fractionations, with the result that six particle-size fractions were obtained. The details of the fractionation procedure which cannot be considered here have been fully reported elsewhere.[5]

The centrifugally determined particle-size distribution curves corresponding to each of these individual fractions appears in Fig. 7. Fraction V is not shown because it is similar to VI. The distribution curves are plotted on semilog paper, which serves to indicate well the percentage variation in equivalent spherical diameter (e.s.d.) of the particles in each fraction, equal distances along the D axis indicating equal percentage variations in e.s.d. The usual distribution function ordinate $f(D)$ has been multiplied by D so that any area bounded by two ordinates under a curve on this plot has exactly the same significance as in Figs. 5 and 6. Considering the difficulties of such a fractionation the relative absence of overlap is truly remarkable.

All fractions analyzed the same chemically and approximated the formula $Al_2O_3.4SiO_2.H_2O$ and, as mentioned previously, all have the same equivalent weight of approximately 1000.

For the purpose of later plots the results are also reported in the form of average equivalent spherical diameters of each fraction. Exactly half of the fraction by weight contains particles with equivalent spherical diameter less than the average as here defined. The average e.s.d. of each of the fractions of which the distribution curve appears in Fig. 7 is as follows: fraction I, 14.3mμ; II, 20.3; III, 28.1; IV, 33.8; V, 87.0.

Fig. 8 shows the six fractions in the form of gels as they were removed from the centrifuge bowl, fraction I, the smallest, being at the left and fraction VI, the largest, at the right. Fig. 9 shows the fractions diluted down to suspensions that had remained undisturbed for nine months at the time of this picture. The order of increasing size can easily be seen from the sedimentation as being from left to right. Fraction I turned out to be of unusual clarity while fraction VI bears more resemblance to an ordinary opaque clay suspension. When stirred, these fractions, particularly the fine ones, exhibit beautiful silky streaks, caused by the platy particles becoming oriented by the stream lines of flow in the liquid and reinforcing each other in the reflection and refraction of light.

Outstanding among the colloidal properties of interest in these systems is the rate at which a given sol will increase in viscosity and transform itself into a gel. The rate of sol-gel transformation is not only of practical moment in the control of muds, but when properly studied it may throw light upon the mechanism of gelatin and the structure of the resulting gels.

When a clay sol sets to a gel the mechanical properties of the gel continue to undergo a change toward some limiting value that would be approached were the gel allowed to stand indefinitely. Thus, the tensile strength of the gel, its yield point, and viscosity all increase with time as long as it is left undisturbed. As soon as the gel is disturbed, the structure being built up within it is affected and the mechanical properties all undergo a change. The difficulties, both theoretically and practically inherent in the physical measurement of any of the mechanical properties of outstanding thixotropic systems like clay suspensions and gels, have been inferred in an earlier section of this paper and are widely appreciated. Many of these difficulties are avoided if one is willing to operate under arbitrarily chosen conditions. In the present instance, it was considered satisfactory to use as a measure of gelation rate the time required for a sol to set to a gel of conveniently selected, though unknown, strength.

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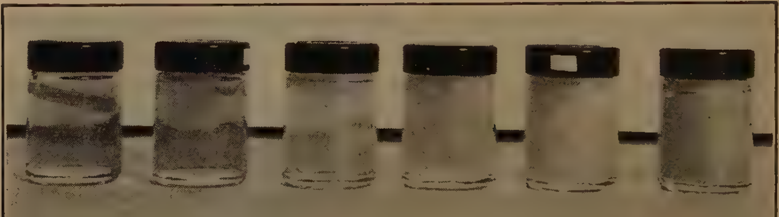

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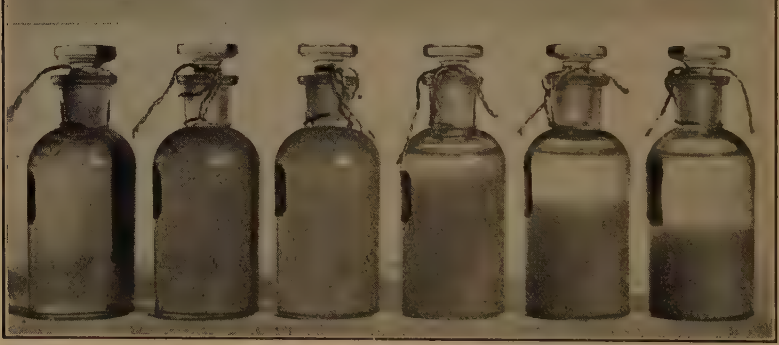

Fig. 8.—Particle-size fraction coming from centrifuge bowl as gels. Increasing size from left to right.
Fig. 9.—Bentonite fractions in sedimentation for nine months.

The technique of obtaining this measurement involved the introduction of a standard quantity of clay suspension of fixed concentration into a Pyrex tube of definite diameter. By trial there was determined the elapsed time necessary before the undisturbed tube could be inverted in a standard fashion with no flow of the contents taking place down the walls. This time has been called the setting time, and its use in measuring gelation has been discussed by Squires and Broughton.[15]

Since the rate of sol-gel transformation is affected by the different ions present in the system, all fractions to be tested were purified of electrolytes by electrodialysis and a suitable amount of a standard electrolyte added. The results are given in Fig. 10, where setting time in minutes is plotted against average e.s.d. The time required to build up a gel of given strength increases enormously with an increase in particle size. It was impossible under any of the conditions represented on this

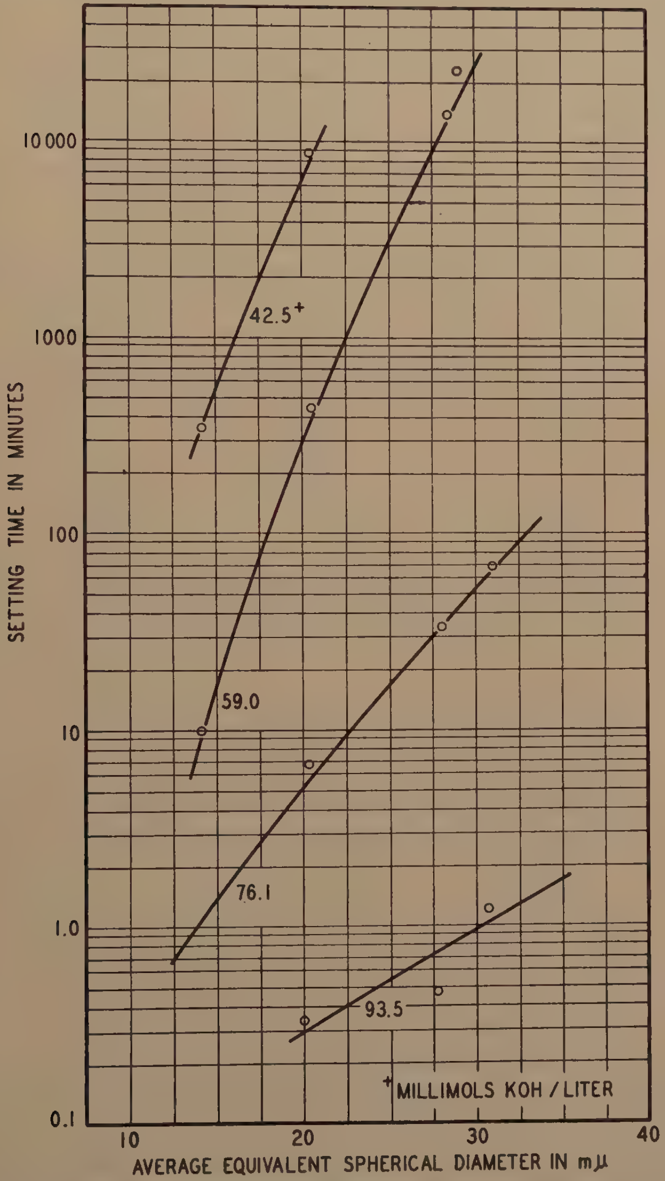

FIG. 10.—THIXOTROPIC SETTING TIME OF 0.85 PER CENT BENTONITE SUSPENSIONS AT 25° C.

plot to observe any evidences of gelation in fraction VI with average e.s.d. of 87 mu. The standard electrolyte used in these tests was KOH, and the setting time undergoes marked decrease with increase in KOH concentration. Similarly, by increasing the concentration of clay it is possible to decrease the setting times in every instance.

While no direct data are available with respect to the final strength of the gels reported in Fig. 10, the fact that under these conditions no evidence of structure could be detected in fraction VI makes it not improbable that, other factors being equal, the facts are that the smaller the particles in a gel of given concentration, the greater its ultimate strength. In this same connection it may be noted that the tendency of the extremely fine fraction I to gel is so great that gel structure may be readily identified at concentrations of bentonite between 0.05 and 0.1 per cent by weight. The method of detecting structure at these low concentrations involves the observation of entrapped air bubbles. These will always rise in a true liquid, no matter how viscous, whereas in a gel, which possesses a yield point, bubbles smaller than a certain critical size will not have the buoyancy to overcome this yield point, and will remain stationary.

The radical difference in behavior effected by particle size forces us to the conclusion that the smallest particles are primarily responsible for the gelation of clays.

Were it practical to effect a particle-size fractionation of the clays composing drilling muds, one would have available a valuable method of control over the mechanical behavior of the muds. Having once obtained the proper particle-size fractions, there is no reason why these might not be blended to give a mud of any desired characteristic.

Effect of Electrolytes on Gelation

Among the more important factors affecting gelation rate, the effect of electrolytes is impressive. An 0.85 per cent suspension of the finest particles of bentonite that have been freed of all exchangeable metallic cations by prolonged electrodialysis shows absolutely no observable trace of gel structure when allowed to remain undisturbed over a period of months, but upon addition of a small amount of concentrated KCl or KOH the same suspension will set almost immediately to a stiff gel. A few drops of concentrated mineral acid also suffices to produce a stiff gel.

It must be emphasized that gelation is independent of pH alone, for it is possible to produce gels of similar characteristics at any point on the pH scale by addition to the suspension of proper quantities of acids, bases or salts.

When hydrogen bentonite is treated with electrolytes, the setting time of the resulting gel does not become constant at once but gradually decreases to a final equilibrium value. During this same period the viscosity measured under any given conditions will also undergo an increase. Fig. 11 illustrates a case where the setting time became constant after 28 days. All of the setting times reported in this paper were taken after 28 days except, of course, some of those in Fig. 11.

While addition of a proper quantity of electrolyte to a hydrogen clay will effect gelation, addition of an excess amount will produce flocculation; that is, the particles will clump together in large masses and settle to the bottom of the container. Table 2 shows that the quantity of KOH required to effect flocculation increases impressively as the average equivalent spherical diameter of the particles decreases.

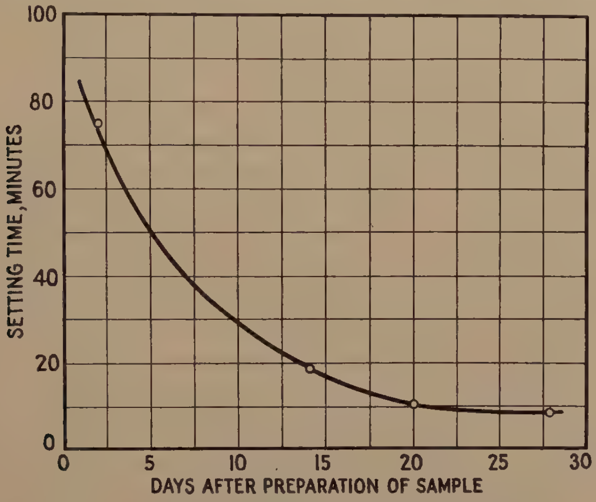

FIG. 11.—AGING PHENOMENA IN A BENTONITE GEL.

Concentration of bentonite = 0.85 per cent. Millimols KOH per liter of gel = 42.5 — temp. = 25° C.

TABLE 2.—*Relation between Flocculation and Average Equivalent Spherical Diameter*

Fraction No.	Average Equivalent Spherical Diameter	Flocculation No.[a]
1	14.3	22–26
2	20.3	16–20
3	28.1	9–10
4	33.8	3–4
6	87.0	1–2

[a] The flocculation number of a given bentonite fraction is arbitrarily defined as the number of milliequivalents of KOH per gram of bentonite required to produce 5 mm. of sedimentation in 24 hr. Tests were conducted with 0.05 per cent sols.

In general gelation is favored by ions of increasing valence. Often when a gel of given strength is produced by addition of a certain quantity of an alkali cation, it is found that the same result may be obtained by addition of a much smaller quantity of some large organic cation like that of tetraethyl ammonium hydroxide. While it is well recognized that many substances of high molecular weight and complex structure like tannin and sodium hexametaphosphate act to reduce viscosity and retard gelation rate, detailed work on such substances is largely unreported. No aspect of the subject offers more possibilities along with more complexities than the study of treating agents.

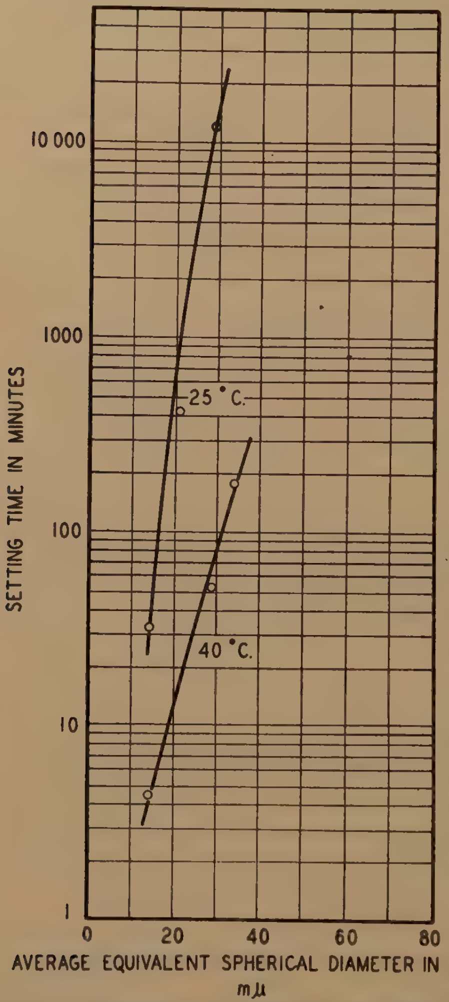

FIG. 12.—EFFECT OF PARTICLE SIZE UPON SETTING TIMES AT DIFFERENT TEMPERATURES. Concentration of bentonite = 0.85 per cent. Millimols KOH per liter = 595.

EFFECT OF TEMPERATURE UPON GELATION

The effects of variation in temperature upon gelation and the mechanical properties of suspensions are so profound that they will be enumerated as several unusually important cases:

1. As shown in Fig. 12, the rate of gelation of potassium bentonite shows a great increase with increase in temperature and qualitatively there occurs a marked increase in viscosity upon heating. Furthermore, upon cooling, the rate of gelation does not fall to its original value but remains high, and the viscosity also remains high. Obviously the change in rate of gelation and viscosity on heating are largely irreversible, the extent of this irreversibility depending upon the time of heating at the higher temperature.

This irreversible increase in viscosity upon heating may well account for some of the thickening that often takes place while mud is in use, as often it becomes heated during passage through the well.

2. Fig. 13 represents data taken in a horizontal capillary-type viscosimeter and shows that hydrogen bentonite has an extrapolated yield point (intercept on pressure axis) independent of temperature and a mobility (slope of reciprocal time-pressure curve) roughly proportional to the fluidity of water. This behavior indicates no significant change in structure upon heating.

3. In contrast to 1 and 2, R. L. Dockendorff[1] has found that no noticeable effect occurs upon heating a suspension of natural bentonite containing sodium and potassium ions above the critical temperature of water, while heating a suspension of acid or hydrogen bentonite above the critical temperature of water effects complete flocculation.

It has been suggested that if a bentonite gel were to be heated sufficiently high, its rate of gelation would eventually decrease. This effect has not been observed to date in the laboratory. In one notable case a gel that took 48 hr. to set at 20° C. set in 5 sec. at 140° C. It is intended to investigate gelation rate at even higher temperatures, but there is some doubt as to the validity of comparing the results to those at lower temperatures, as deep-seated, irreversible changes may occur in the clay particle itself.

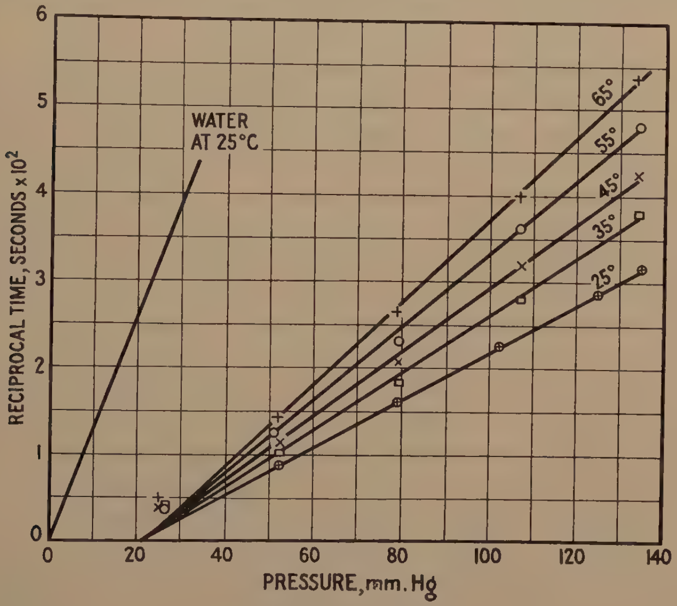

FIG. 13.—EFFECT OF TEMPERATURE ON FLOW PROPERTIES OF H-BENTONITE, FRACTION 6 (2.08 PER CENT).

GEL STRUCTURE AND THE MECHANISM OF GELATION

All of the facts set forth in preceding sections must serve as guiding lights in the formulation of any successful theory of gel structure. At the present time it is possible to offer convincing explanations of many of the most important facts, even though no theory has been developed in enough detail to permit satisfying explanations of all known facts.

It has been emphasized repeatedly that all investigators agree that gelation involves the production of a structure resistant to shear in which the ultimate particles are locked firmly into place. Disagreement occurs only when attempts are made to offer explanations as to how the particles are locked into place.

The earliest theory proposing to account for the gelation of clays was the so-called hydration or solvated-hull theory. The hydration theory assumes that the particles adsorb upon their surfaces thick layers of water in such a compressed and semifluid state that they may coalesce. When these water layers have grown to suitable thickness, coalescence may take place throughout the entire volume of the system, with the resulting immobilization of the particles that now find themselves locked into position in a gel.

The most impressive experimental evidence against the solvated-hull theory lies in the effect of temperature on gelation. There is abundant evidence throughout colloid chemistry to indicate that the solvation of a particle generally decreases enormously with an increase in temperature and acceptance of the solvated-hull theory would lead one to predict an increasing tendency toward gelation at the lower temperature, whereas actually exactly the opposite effect is observed.

Lewis, Squires and Thompson[11] have proposed an essentially mechanical picture of the gelation process in clays. This theory focuses attention upon the platelike shape of the particles and assumes that as a result of innumerable almost exclusively edge-on collisions caused by Brownian movement the particles become wedged together in complete random orientation. The particles are conceived as being packed close enough so that movement of any one particle is prevented by mutual contact with its neighbors, this immobilization resulting in a gel structure.

To account for the appearance of gel structure on the basis of particle interference at a concentration of clay equal to 0.1 per cent, the mechanical theory is forced to assume the existence of platelike particles with ratios of length and breadth to thickness of upwards of 1000 to 1. Although the layer lattice structure of clay indicates that these extremely platy particles could be stable and rigid, it must be remarked that there is no positive microscopic evidence that they have such extreme ratios of length to thickness as 1000 to 1. On the other hand, difficulties inherent in the present microscopic technique for accurate determination of size and shape of particles of colloidal size tends to weaken the weight of this evidence against the extreme dimensions postulated by the mechanical theory.

In order to explain the known facts without the assumption of extreme ratios of length to thickness, a third theory, which will be referred to as the attraction-repulsion theory, assumes the existence of two sets of forces between particles—a repulsive force of electrostatic nature resulting from the mutually repellent effect of the ions that dissociate from the surface and surround the particle, and an attractive force of the Van der Waals type.[2,3] These opposing sets of forces acting between particles vary in different manners with the distances between particles, particle size and shape, the concentration and type of electrolyte present, etc., and it is possible for the variations to be such that at one critical distance the attractive force will exactly balance the repulsive force. When two particles are separated by this critical distance there is no tendency for them to move, because when they approach closer than the critical distance the repulsive force increasing faster than the attractive force causes them to be repelled, while if they separate to a distance greater than the critical distance the attractive force increasing faster than the repulsive force causes a net attraction, which returns them to the critical distance of separation where all forces are balanced. Particles separated by this critical distance are thus effectively locked into place and a gel is formed.

The chief difference between the mechanical theory and the attraction-repulsion theory lies in the average distances assumed to exist between the particles in the gel. Both theories conceive a gel structure composed of particles locked into fixed positions in completely random orientation, but in the mechanical theory the platy particles are assumed to have a ratio of length to thickness great enough so that their edges are in mechanical contact, whereas in the repulsion-attraction theory the particles are assumed to be held in place by relatively long-range forces of attraction.

At present the mechanical theory offers eminently satisfactory explanations of the properties of concentrated clay gels like 40 per cent kaolin, where extreme ratios of length to thickness do not have to be assumed to account for structure formation by particle interference. However, further experimentation will be necessary to establish which of these concepts is correct for gels occurring at the extremely dilute concentrations of clay of 0.1 per cent or less.

The preceding theories have assumed that the ultimate platelike particle composed of a stack of crystallites is the structural unit in the gel. In contrast to this it is possible that the platy particles may undergo an oriented coagulation lapping over each other face to face, with the resultant formation of large platy aggregates, which act as structural units in the gel in the same manner as individual particles. Indeed, there is some evidence that a gel is composed of both primary particles and secondary platy aggregates.

In Fig. 14 are reported the results of several runs on 4.5 per cent bentonite suspension in the MacMichael viscosimeter.[7] Since the whole plot is at 105 r.p.m., the deflection in degrees MacMichael may be taken as proportional to the viscosity measured at substantially constant rate of shear. Considering, for the moment, only that portion of the plot below a time of rotation of 70 min., three significant types of curves are obtained, depending upon the time after vigorous agitation that the suspension was allowed to set in the viscosimeter cup before rotation was begun. With zero initial set, the viscosity increases continually from a low to some asymptotic value, while with an initial set of 17 hr. the viscosity decreases continually from a high to some asymptotic value, which may well coincide with that reached in connection with zero initial set. Between these two limiting cases occur two runs of 15 min. and 1 hr. initial sets, respectively, in which the viscosity decreases from a relatively high initial value, goes through a minimum and begins to increase to asymptotic values, which again may well coincide with those in the limiting cases. The asymptotic values of deflection are those existing at the time when the gel structure has reached a state of dynamic equilibrium, the rate of breakdown due to rotation of the viscosimeter just balancing the rate of build-up produced by Brownian motion forcing particles into their positions of mutual interference.

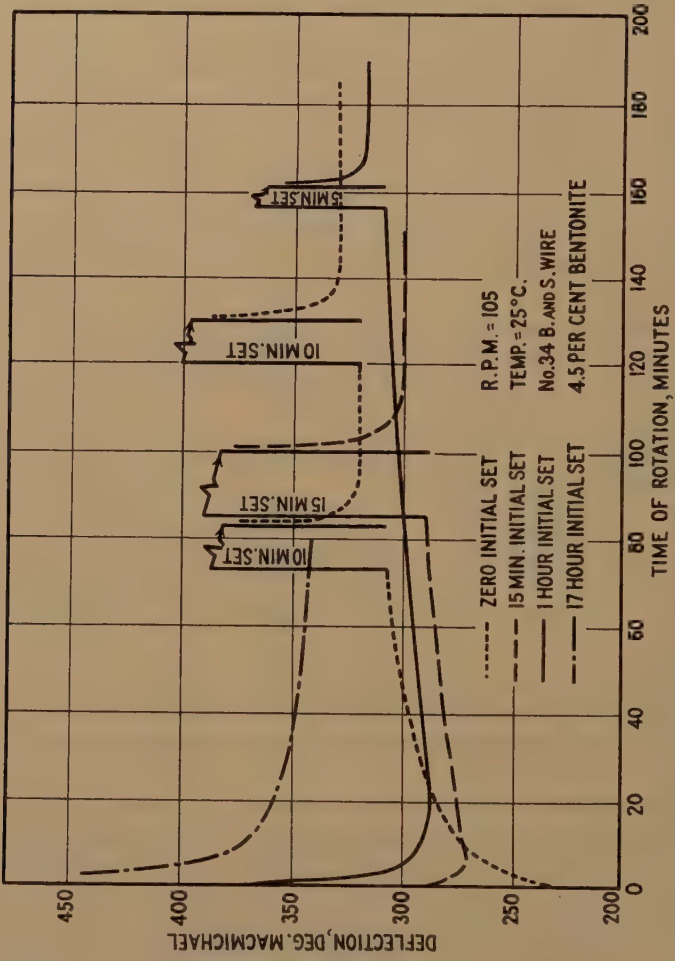

FIG. 14.—DEFLECTION VERSUS TIME. EFFECT OF INITIAL AND SUBSEQUENT SET PERIODS.

If it be assumed that the formation of a gel structure results from two different mechanisms working simultaneously, perhaps at rates varying with the time of rotation, the behavior in Fig. 14 becomes understandable.[12] In the case of zero initial set there was no structure built up at the start of rotation, the deflection being due entirely to the viscosity of the suspending liquid and the viscous drag of the suspended particles through the liquid. As time goes on a structure is built up by operation of both mechanisms, until finally at equilibrium the rate of breakdown becomes equal to the rate of build-up. In the 17-hr. initial set a structure of substantial strength has already been formed by the joint operation of both mechanisms, only to be broken down to an equilibrium value by rotation of the viscosimeter. In the intermediate set periods, the first mechanism contributing to structure has built up much of its portion of the structure and is now working slowly while the strength of the structure is being increased at a more rapid rate by the second mechanism. When rotation starts that portion of the structure produced by the second mechanism not having had time to reach sufficient strength is the first to be broken down, depressing the deflection to a low value, which recovers, however, because of the ever-continuing activity of the first mechanism.

While the nature of the two mechanisms is still in doubt, a most appealing suggestion is that the first mechanism consists of an oriented face to face coagulation of the individual clay particles resulting in secondary platy aggregates of increased ratios of length and breadth to thickness, and therefore of increased capacity for mechanical interference with each other.[10] The second mechanism consists of the wedging into place of both secondary aggregates and remaining unaggregated primary particles into the gel structure. Obviously, the more platy the particles, the more readily will the second mechanism occur; hence its effect in producing a structure undergoes increasing acceleration as the first mechanism continues to produce the desirable secondary aggregated particles of increased ratios of length and breadth to thickness. At the same time, it is easier to break up a secondary structure of aggregates than to break up the aggregates themselves or prevent their continuing formation, thus accounting for the minima in the curves of intermediate initial set.

Recent ultramicroscopic observations[5] where under some circumstances two distinct types of structure were noticed are additional evidence in favor of the two-mechanism formation of gel structure.

Both the mechanical and repulsion-attraction theories predict that decreasing particle size will increase the rate of gelation because of the enormous increase in Brownian movement caused by a decrease in particle size. In the mechanical theory increased Brownian movement causes an increase in rate at which the particles become wedged into place in the gel, whereas in the repulsion-attraction theory the particles have a greater chance to vibrate into the critical relative positions from which they have no tendency to depart because repulsive and attractive forces are in balance.

Since rise in temperature increases Brownian motion, its effect upon increasing the rate of gelation is likewise predicted by both theories.

The explanation for the behavior of electrolytes, in brief, is that by modifying the extent of the dissociation of ions from the surface of the individual clay particles a profound change is effected in the magnitude and variation of the repulsive forces between particles. Also, owing to the change in thickness of the ionic atmospheres, a profound modification in interparticle friction is to be anticipated with a resultant change in the rate of gelation, ultimate gel strength, and viscosity.

Important Unsolved Problems of Clay Behavior

Measurement of Mechanical Properties of Clay Suspensions and Gels.—The viscosity, mobility and yield point of a clay suspension are all complex functions of the rate of shear, the time of shear, and the past history of the suspension. Typical of the complications entering into any measurement of the flow properties of a clay suspension are those illustrated in Fig. 14, where, as has already been seen, the deflection (which is proportional to the viscosity at constant rate of shear) varies widely with the time of initial set before shear and with the time of shear. The effect of shearing history is further demonstrated by the intermediate periods of set during which the viscosity increases, to an amount depending upon the time of set.

Not only will viscosity, mobility, and yield point increase in an undisturbed suspension (thixotropy) but it is even possible to accelerate their increase by application of the proper type of mechanical agitation.[6] For example, a small tube of potassium bentonite allowed to stand undisturbed for an hour had set to a gel just strong enough to support its own weight upon inversion, no flow taking place down the walls of the tube. The same tube vigorously agitated until the suspension within it became a freely flowing sol was subjected to a gentle tapping motion, whereupon it set to a gel of the same strength in 50 sec., a seventy-five fold increase in gelation rate. This increase in gelation rate induced by mechanical action is called rheopexy.[6]

In the face of such complications it is not surprising that almost no progress has been made toward the quantitative characterization of flow properties of clay suspensions. Clearly, when it is constantly necessary to study the effect of different variables upon the sol-gel transformation where the only detectible differences are mechanical differences, it is important to develop methods of measurement which will distinguish between sol and gel in a precise, quantitative manner. Considerable research must continue upon methods of measurement in the future.

Electrochemical Behavior of Clay Suspension.—Recent work[5] has shown that the hydrogen-ion activity of suspensions of hydrogen clay measured by a glass electrode is independent of the particle size and is so great that on this basis alone hydrogen clay could be classed as an acid of far greater strength than would correspond to the ordinary chemical properties of the silicon and aluminum of which it is composed. On the other hand, the hydrogen-ion activity of a suspension of hydrogen clay calculated from its electrical conductance is, depending upon the particle size, only one fifth to one half as great as the electrometrically measured activity. Although the complete interpretation of this significant discrepancy, which increases as the particle size decreases, is as yet obscure, it should be remembered that while electrometric measurements are essentially equilibrium measurements involving no displacement of ions from the clay particles, conductometric measurements are essentially non-equilibrium measurements and involve a displacement of the ions from the particles. The lower value of hydrogen-ion activity obtained from conductance measurements may be additional evidence of the intensity with which the ions in the ionic atmosphere are bound to the clay particle. Additional research into the electrochemical behavior of clay cannot help but lead to a more complete knowledge of its structure.

Effects of Addition Agents.—With the exception of the simplest electrolytes whose behavior in the ionic atmosphere surrounding the clay particles is to some extent understood, knowledge of the effects of addition agents is entirely empirical. Such a lack of knowledge is understandable in view of the fact that to date it has been necessary to center all efforts upon acquiring a working picture of the structure of the clay particle and of clay sols and gels in order to have available a sound basis on which to interpret the effects of addition agents. In view of the profound effects which addition agents may exert upon the mechanical properties of suspensions and gels, it is certain that they will occur prominently in future research.

Conclusion

It is now recognized that the ultimate particles of clay consist of platelike crystallites stacked upon each other like a pack of cards. The high swelling, high viscosity, and pronounced gelation tendencies of bentonite as contrasted with kaolinite are explained by the water molecules forcing their way between the crystallites and prying these apart with resultant formation of platy particles having unusual capacity to interfere with each other and with the flow of the liquid in which they are suspended. This interference of the particles may develop to such an extent that each particle is no longer free of its neighbors but requires a finite force to dislodge it from a position in the gel structure into which it has become locked. The data definitely indicate that those clay fractions consisting of the finest particles show the highest rate of gelation. Metallic clays are known to undergo an irreversible increase in viscosity and rate of gelation upon heating to moderate temperature levels as contrasted to hydrogen clays which show no significant changes in structure under the same circumstances.

The key to interpretation of these facts lies finally in recognition of the mechanism by means of which the ultimate platy particles become firmly locked into place in a structure. It is possible to account for the facts on the basis of mechanical interference of platy particles if the existence of very large ratios of length and breadth to thickness of the ultimate plates be assumed. Along with the mechanical interference theory it is necessary to recognize that the facts may be explained by the repulsion-attraction theory which instead of demanding the assumption of excessive ratios of length to thickness demands assumption of the existence of far-reaching forces of attraction and repulsion to bind the particles into equilibrium positions from which they have no tendency to depart. In the final analysis, the two theories differ only in the average distance they assume between particles in the gel and both are fruitful working theories at present. Final decision between the two theories, or perhaps their combination, will come only when we have more direct evidence of the dimensions of individual particles as well as the forces acting between these particles.

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Intensive Weighting of Petroleum Drilling Muds with Galena

By Henry Emmett Gross,* Member A.I.M.E.

(Oklahoma City Meeting, October, 1937)

Recently, areas of abnormal rock pressure have been drilled on the Gulf Coast of the United States. These pressures may be caused by the recent and pronounced raising of some of the structures without loss of the formation pressure that existed when the reservoir was developing and the producing sand much more deeply buried. It is possible also that a permeable fissure may connect a shallow accumulation of gas with the gas cap of a much deeper reservoir of oil, gas and water. The pressures are so great that dependence on blowout-prevention equipment alone is hazardous to life and property. Fortunately, wells with excessive casinghead pressures, such as the Stanolind Oates No. 1 of the South Houston field, an 8700-ft. gas well with 6000 lb. per sq. in., and the near-by Stanolind Candelari No. 1, and 8100-ft. gas well with 5000 lb. per sq. in., have not blown out and cratered. A case is on record of drill pipe in a well in Harris County, Texas, (Oates No. 1) rotating for 8 hr. through blowout-prevention rams holding a back pressure of 2900 lb. per sq. in. at the casinghead after the mud was altered by salt-water intrusion. Such conditions warrant the use of extremely heavy muds having low viscosity, made from galena (PbS) or specially prepared mixtures of hematite (Fe_2O_3) and galena suspended by bentonite.

In some Gulf Coast wells, sodium silicate mixed with concentrated brine is used to drill through heaving shale formations. Such a fluid inhibits heaving remarkably, but it is expensive and costs as much as $10 per barrel. Barite has been used to weight this mixture. However, this mineral too rapidly increased an already excessive viscosity and it was thought that galena might be better for weighting such drilling fluid. The operator was anxious to try the latter, but none was available in the district.

Laboratory Study of Heavy Muds

To foster the use of the plentiful and extremely heavy mineral, galena, research has been done recently at the University of Oklahoma to determine the mud-making properties of this substance. For comparative

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purposes the characteristics of the muds of galena, hematite, barite, and 50-50 blends by weight of galena-hematite, and galena-barite were studied.

All of these muds were composed of minus 325-mesh Tyler material suspended by bentonite according to the following pattern. Consider the weight material, whether a single mineral or a 50-50 blend of two as "substance A." A slurry of bentonite (4 per cent by weight) in Norman tap water is designated as "substance B." Theoretically substance A and substance B were mixed in various proportions from 10 to 65 per cent or more weight material. Actually specified amounts of the dry powders, both weight material and bentonite, were dry-mixed thoroughly, and gradually added by spatula to a predetermined amount of tap water. The water was stirred continuously in a malt mixer while the powders were added, then the mud was mixed for 20 minutes.

Thixotropic Characteristics

Although unorthodox, the method of mixing described above was used because after the viscosities at various rates of shear were obtained and the specific gravity taken for a given mud mixture, bentonite equivalent to 1 per cent by weight of the mud was added, and the mud characteristics again determined. These 1 per cent increments were continued until the mud became too stiff for Stormer readings. In this way no bentonite was added to the water before the weight material, and all combinations of weight material and bentonite were studied thereby for thixotropic characteristics. The results for a galena-hematite 50-50 blend by weight studied in this manner are presented graphically in Fig. 1. It is true that the properties shown on this graph are different from those of muds mixed in the orthodox manner, but to have developed this graph from the characteristics of muds that were prepared by having all bentonite thoroughly mixed into a slurry before adding weight material would have required the preparation of a myriad of muds, entailing endless time. It is more logical to make the graph as has been done, then make corrections by running determinations on properly built muds. Fig. 1 shows that to increase the viscosity at a given rate of shear there must be added either more weight material or more bentonite, or both. Also, a given mud tends to stiffen or become more viscous as its motion is retarded. The proximity of the 10-centipoise, 300-r.p.m. curve to the 5-centipoise 600-r.p.m. curve at high concentrations of bentonite indicates that the thixotropic characteristic is due primarily to this mineral. Muds that contain sufficient bentonite to have a viscosity of 15 centipoises or more, without excessive weight material, tend to age into stiffer muds after setting one or more hours.

Plans were made to present, for comparative purposes, a similar curve for galena-barite 50-50 blends, but it was learned too late that the sample of barite used had 3 per cent bentonite ground into it at the mill. The

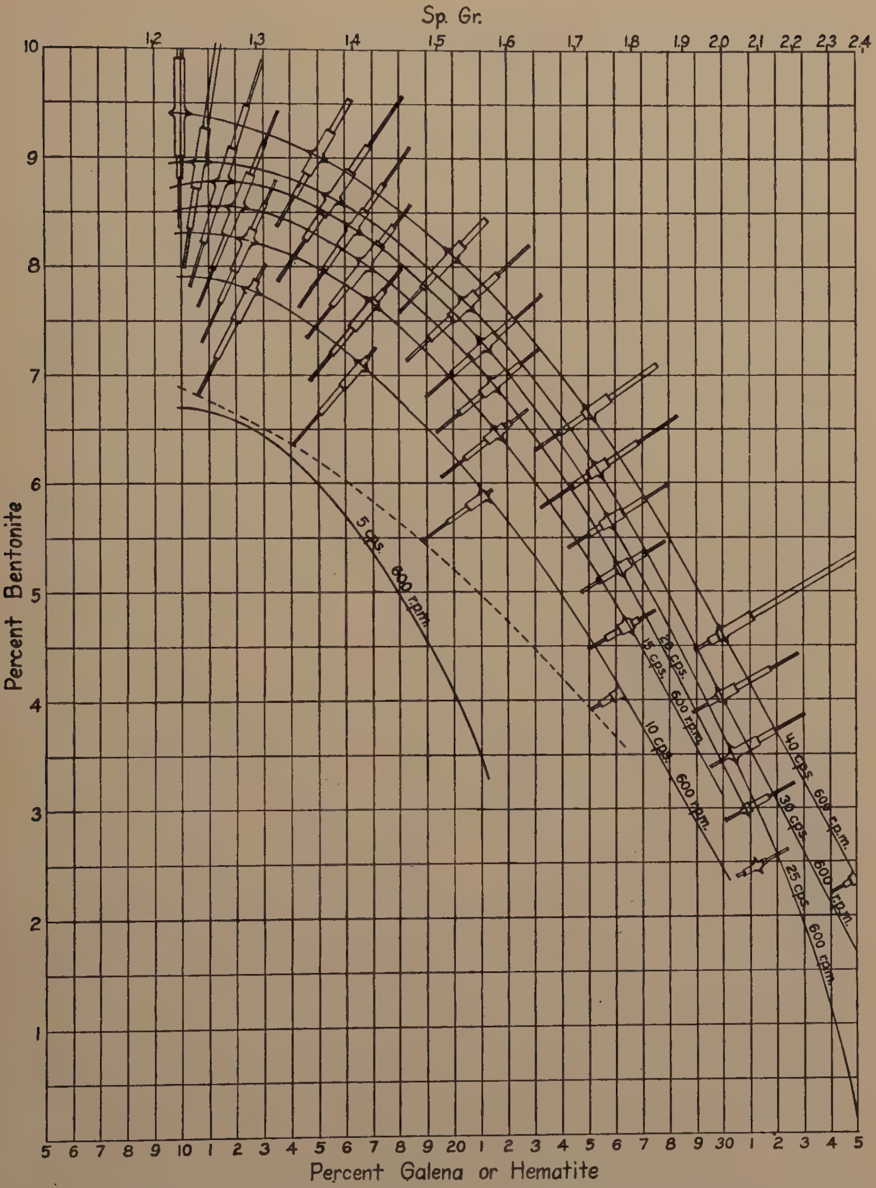

FIG. 1.—THIXOTROPIC CHARACTERISTICS OF GALENA-HEMATITE FIFTY-FIFTY BLEND. The viscosity at the greatest diameter of a barb falls on a 600 r.p.m. curve. The first telescopic joint toward the origin of the graph on that barb represents the same viscosity on the 500-r.p.m. curve. The end of the barb nearest the origin represents the 300-r.p.m. curve. The first telescopic joint radiating away from the connection of a barb to the 600-r.p.m. curve represents the 700-r.p.m. curve. In this manner the 10-centipoise, 300-r.p.m. curve, or any others, may be visualized. See dotted line.

results of research on such mud would give an unfair and unfavorable impression. A sample of pure barite was obtained, but not in time for the necessary thixotropic determinations.

WEIGHTING CHARACTERISTICS OF HEAVY MINERALS

A comparative idea of galena-hematite and galena-barite blends is given in Table 1. A galena-hematite mud weighing 20 lb. per gallon (sp. gr. 2.4) has a viscosity of 28 centipoises at 600 r.p.m. Stormer with fin. Tannic acid will not reduce the viscosity of this mixture. If an identical amount of barite is substituted for the hematite in this mud, the viscosity is 75 centipoises, but tannic acid then will reduce the viscosity greatly, and 0.1 per cent by weight of tannic acid added to the mud will reduce the viscosity to 40 centipoises, other characteristics being the same as for the galena-hematite mud.

TABLE 1.—*Comparison of Blends*

Galena, Wt. Per Cent	Barite[a] or Hematite, Wt. Per Cent	Bentonite, Wt. Per Cent	Water, Wt. Per Cent	Specific Gravity of Mud	Pounds per Gallon of Mud	Viscosity,[c] Centipoise	
						Barite-galena Blend	Hematite-galena Blend
5.0	5.0	3.6	86.4	1.11	9.3	2.4	1.7
10.0	10.0	3.2	76.8	1.22	10.1	3.4	1.7
15.0	15.0	2.8	67.2	1.35	11.3	6.0	2.1
20.0	20.0	2.4	57.6	1.52	12.7	10.0	3.3
25.0	25.0	2.0	48.0	1.72	14.3	11.0	6.6
30.0	30.0	1.6	38.4	2.00	16.7	20.0	8.9
35.0	35.0	1.2	28.8	2.37	19.8	68.0	28.0
37.5	37.5[b]	1.0	24.0	2.62	21.9	No go	52.0
40.0	40.0	0.8	19.2	2.91	24.3	No go	No go

[a] Note that the barite and the hematite samples used each had a specific gravity of 4.35, which was a fortunate accident and permits a better comparison of products. Therefore of the intensive mud weight dry blends discussed each has a theoretical specific gravity of 5.4.

[b] Too stiff or viscous when using barite and almost too stiff with hematite.

[c] Viscosity in centipoises as determined by Stormer with fin at 600 r.p.m. spindle velocity. Muds of composition shown in first four columns. No tannic acid viscosity reducer used. Hot June and July Oklahoma weather, 90° to 104° F.

Fig. 2 gives an idea of the large quantities of weight material necessary to keep a mud in the desirable viscosity range of 15 to 25 centipoises for good pumpable muds. Throughout this viscosity range a higher percentage of galena-hematite 50-50 blend weight material can be added than for the other muds, and up to 25 centipoises this blend will produce the heaviest mud for any given viscosity. This is shown in Fig. 3, on which the specific gravity, or pounds per gallon, is plotted on the abscissa and viscosity on the ordinate. Above 19 lb. per gal., pure galena mud affords the best viscosity characteristics, and although beyond the best viscosity range, this mud does not become too thick to pump until it passes a specific gravity of 3.

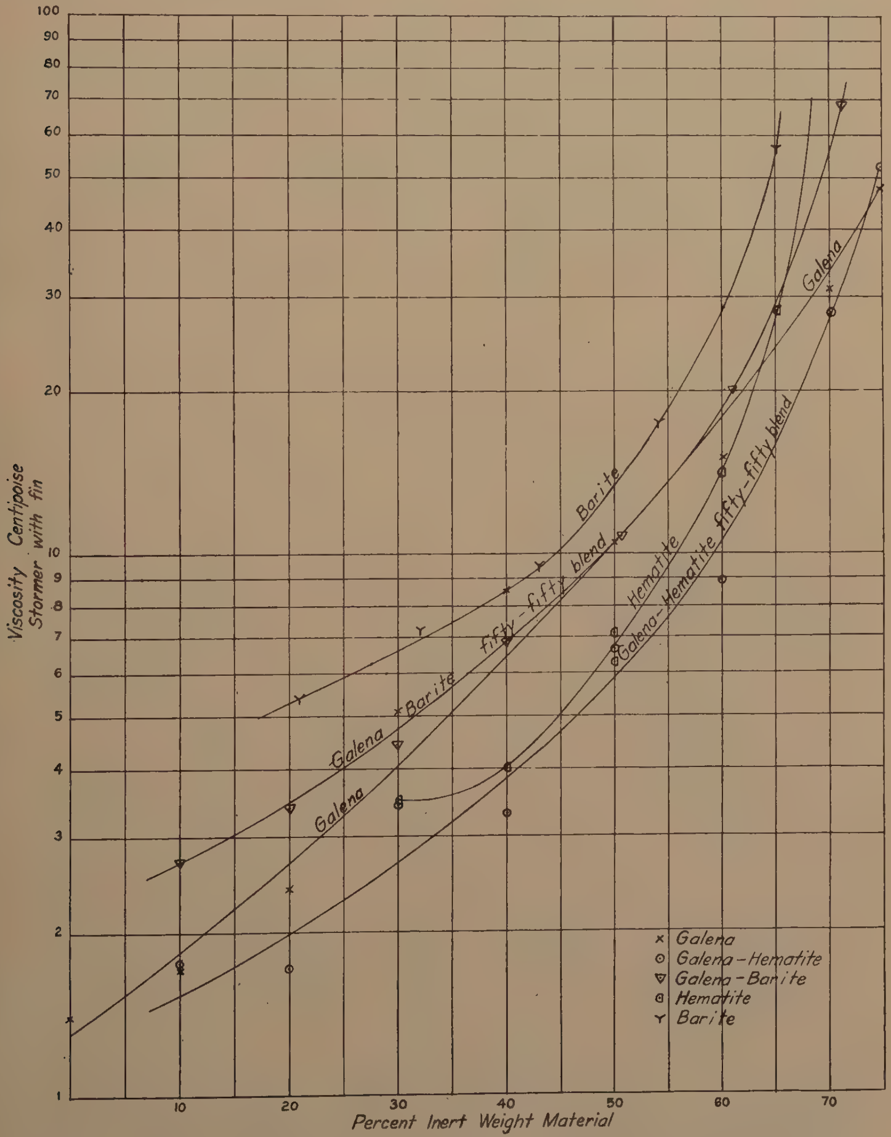

FIG. 2.—AMOUNTS NECESSARY TO KEEP MUD IN DESIRABLE VISCOSITY RANGE.

WALL-BUILDING CHARACTERISTICS

Filter-press determinations were made on the muds of various weight materials and their blends, with the results illustrated in Fig. 4. The muds containing hematite and the barite-galena blend do not have attractive wall-building characteristics, and indicate that thick and undesirable

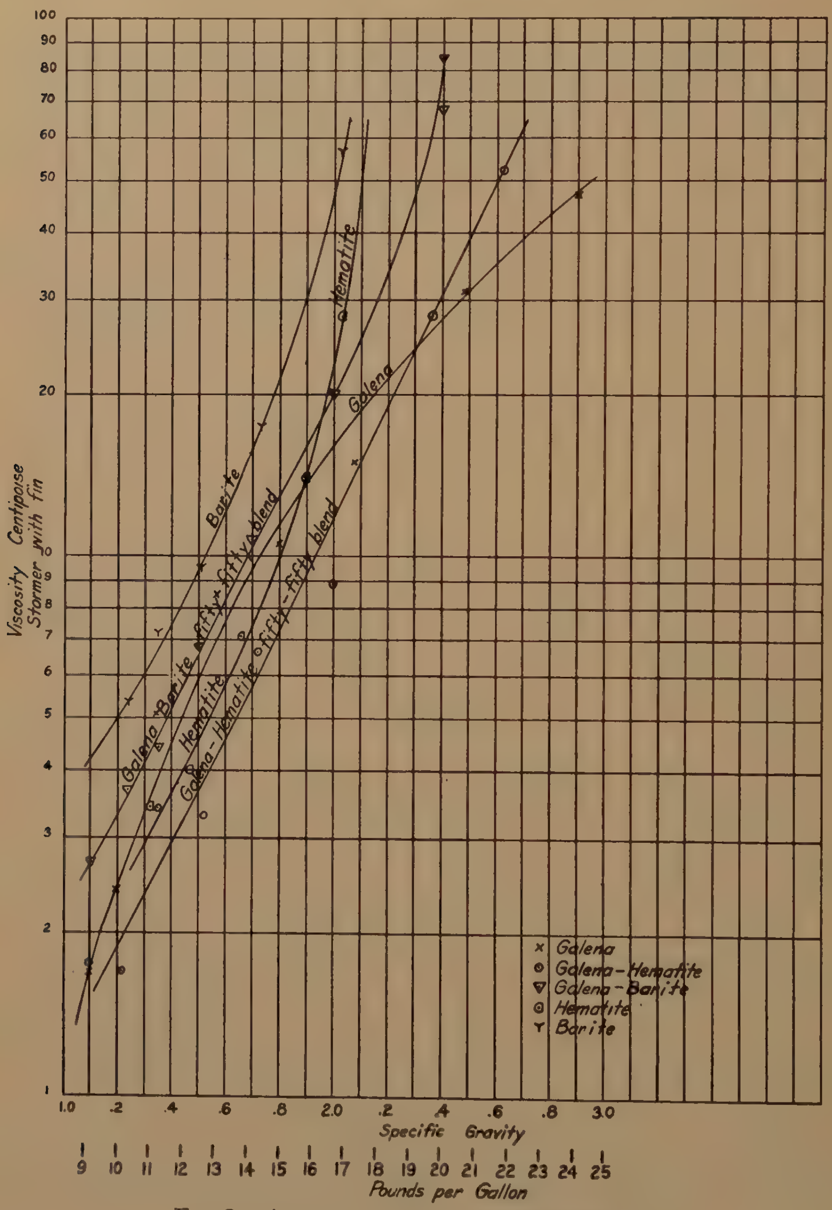

FIG. 3.—AMOUNT OF GALENA IN DESIRABLE MUD.

mud sheaths inducive to stuck drill pipe might be built. Pure galena and barite muds have thin filter cakes, which indicate better mud-sheath qualities. Table 2 supplements Fig. 4. Galena might be expected to have good wall-building characteristics, since addition of this substance to bentonite slurry causes a preferential removal of bentonite from the slurry by this weight material. This shows the affinity of bentonite for the galena mineral surface.

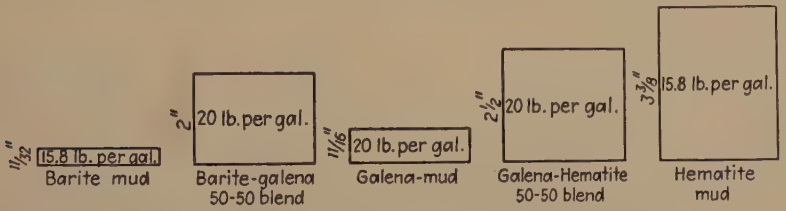

FIG. 4.—FILTER CAKES BUILT FROM HEAVY MUDS.

TABLE 2.—*Wall-building Characteristics*

Composition, Per Cent	Specific Gravity	Viscosity,[b] Centipoise	Thickness of Filter Cake, In.	Time to Cake, Min.	Pressure on Press, Lb. per Sq. In.	Characteristics of Cake
Galena, 35.5 Barite, 35.5 Bentonite, 1.15 Water, 27.85	2.40	68.0	2	5½	1000	Very stiff putty
Galena, 35.0 Hematite, 35.0 Bentonite, 1.2 Water, 28.8	2.37	23.0	2½	2½	2000	Hard briquette
Galena, 67.0 Bentonite, 1.3 Water, 21.7	2.41	21.0	1/16	7½	500 to 1000	Soft putty
Barite, 60.4[a] Bentonite, 2.16 Water, 37.4	1.91		1/32		1000	Hard briquette
Hematite, 59.7[a] Bentonite, 2.2 Water, 38.1	1.90		3⅜		1000	Hard briquette

[a] Samples run at the Tulsa laboratory of Baroid Sales Division of National Lead Co.
[b] Stormer with fin at 600 .p.m. rHot summer weather, 85° F.

pH VALUES OF GALENA MUDS

In determinations made on muds containing galena, the pH was found to be from 5.2 to 5.5, compared to tap water of 7.6 pH. This may be attributed to oxidation of the surface of the mineral particles during the extremely fine grinding to minus 325-mesh Tyler. The corrosive action of galena mud on a bright tin can was not excessive after three weeks. Although the powdered galena forms acidic mud, it should be possible to buffer this mineral to a favorable alkalinity or inhibit the acid so that it would not be harmful to casing, and there should be no further decomposition in an oil-well borehole. As found in nature, the mineral galena surely has been exposed to the oxidation and acid conditions of ground water and has resisted them through long periods of geologic time, even at the very grass roots. With such inherent stability of this mineral, it should be easy to correct the acid condition of the powder permanently. Di-sodium phosphate is one chemical that is used in industry as an alkaline buffer and also as a viscosity reducer for muds.

Availability and Cost of Minerals

Galena is the most abundant and cheapest of the intensive weight minerals having a specific gravity of more than 7. The St. Joseph Lead Co. (sole producer of the Southeast Missouri lead belt) estimated that production from its mines in 1937 would be 140,000 tons of pure pig lead, and its maximum capacity is 175,000 tons per year. Sixty per cent of the lead is obtained from high-grade table concentrates of minus 14 plus 200-mesh Tyler. The material is 80 per cent Pb with a trace of pyrite and limestone gangue. Considering the difference between present mine capacity, and at the current rate of production, as much as 40,000 tons of galena could be available from the lead belt alone for years to come. This big and progressive producer could grind and prepare to specifications large quantities of this material.

Eagle Picher's smelter at Galena, Kansas, is receiving from Washington State 600 tons per month of 80 per cent minus 325-mesh Tyler, 80.7 per cent Pb, galena flotation concentrate. The St. Louis Smelting and Refining Co., a sister company of Baroid Sales, is producing 300 tons per month of 84 per cent Pb, galena gravity concentrate at its Baxter Springs plant, Kansas, from which the sample used for the research in this paper was obtained. From such production, the petroleum industry should be able to obtain a plentiful supply of galena for wells needing an intensive mud weight. At $85 per ton f.o.b. the lead belt, galena alone is too expensive, but a 50-50 blend with $12 per ton iron ore (hematite) would bring the cost within the range of usefulness. With hematite and barite selling for $40.15 per ton in Oklahoma City, it is evident that galena could not be considered as a competitive mineral, but rather as a special intensive mud weight filling a limited requirement. If a half dozen deep wells (7000 to 10,000 ft.) should each require 1000 tons of such intensive mud weight blend per year, the use of galena muds as described would benefit both the oil-well drilling industry and the Middle Western lead-mining industry.

CONCLUSION

There are special conditions in excessively high-pressure wells that warrant the use of heavier and thinner muds to relieve pressures on blowout-prevention equipment. Most instances that would justify these intensively weighted drilling fluids have narrow mud-weight tolerances above which the mud is dissipated into lower pressure formations and below which it is gas-cut or upset by salt-water intrusion. However, there are several cases on record of 17 lb. or more per gallon mud being used to control deep wells. Viscosity reduction for such a fluid is an important item and could be accomplished by the use of galena. Pure galena muds have good wall-building characteristics, and this soft, friable mineral is not abrasive to pump parts. The acid nature of galena muds can be corrected by buffering. Galena is an abundant heavy mineral but its high cost will prevent indiscriminate use, although there are conditions in which it can give a specially needed service.

ACKNOWLEDGMENTS

Gratitude is expressed for the diligent work and helpful suggestions of my student, Mr. Nicholas A. Kaldenbach, who for six years before coming to the University of Oklahoma was a petroleum engineer for the Shell Company in the Dutch East Indies. Thanks are due also to Mr. A. E. Bendelari, President of the Eagle-Picher Lead Co., and Mr. J. A. Caselton, Vice President of the St. Louis Smelting and Refining Co., for their cooperation in supplying well prepared samples of very finely ground galena. Mr. L. T. Sicka, General Manager of St. Joseph Lead Co., Bonne Terre, Mo., gave valuable information on the abundance and fine quality of Southeast Missouri galena. Mr. R. C. Marr, of the Baroid Sales Co. of Tulsa, assisted in some of the determinations and gave much needed criticism and suggestions.

DISCUSSION

(*L. L. Foley presiding*)

R. C. MARR,* Tulsa, Okla. (written discussion).—As supplementary data to Mr. Gross' paper I would like to cite the following results of preliminary tests conducted in one of our laboratories on muds weighted with galena, barite and hematite.

Inasmuch as it is customary on the Gulf Coast to start with a native mud weighing in the neighborhood of 9½ lb. per gal. and add weighting material to this to produce the heavy muds, our tests were made with a native mud from the Hastings field near Houston, according to the following procedure:

Preparation of Weighted Muds.—Calculated quantities of Hastings mud and weighting material were put into a Hamilton-Beach mixer and agitated at high speed for 5 min. The viscosity of the mud was then measured with a Stormer viscosimeter operated at 600 r.p.m. and the mud density checked with a Braun Mudwate hydrometer. Some samples of the mud were further treated with 1 c.c. of Stabilite No. 4 to 500 c.c. of mud.

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* Service Engineer, Baroid Sales Dept., National Lead Co.

Carver Press Test.—To determine the wall-building characteristics of each mud, a suitable quantity of that mud was prepared in the cell of the Carver press and subjected to a pressure of 1000 lb. per sq. in., causing filtration through a filter pad of ½ in. thickness. A time record was kept of the volume of filtrate. At the end of 30 min., the thickness of the cake deposited on the filter pad was measured.

Table 3.—*Tests at Baroid Sales Department Laboratory*

Weighting Material			Mud, Grams Used	Stabilite, C.C.	Weight of Mud, Lb. per Gal.	Viscosity, Centipoise	Cake Thickness, In.	Total Filtrate, C.C.
Name	Sp. Gr.	Grams Used						
None....			570	0	9.5	8.2	0.06	17
			570	1.0	9.5	5.0	0.06	16
Barite....	4.35	197	523	0	12	10	0.09	20
Barite....	4.35	361	479	0	14	17	0.19	22
Barite....	4.35	524	436	0	16	30	0.31	26.5
Barite....	4.35	854	346	0	20	102	0.88	30
Barite....	4.35	854	346	1.0	20	90	0.88	24
Hematite	4.55	194	526	0	12	15	0.44	75
Hematite.	4.55	385	485	0	14	25	1.38	142.5
Hematite.	4.55	520	440	0	16	42	3.06[a]	185[a]
Hematite.	4.55	680	400	0	18	118	4.0[a]	220[a]
Hematite.	4.55	680	400	1.0	18	115	3.9[a]	212[a]
Galena...	7.31	462	498	0	16	30	0.19	22
Galena...	7.31	462	498	1.0	16	14	0.16	19
Galena...	7.31	746	454	0	20	85	0.38	33
Galena...	7.31	746	454	1.0	20	31	0.25	23.5
Barite....	5.45	492	467	0	16	32	0.19	21
Galena...	5.45	492	467	1.0	16	16	0.19	18
Galena...	5.45	797	403	0	20	65	0.56	31
Galena...	5.45	797	403	1.0	20	42	0.45	24.5
Hematite.	5.61	490	470	0	16	31	1.25	114
Galena...	5.61	490	470	1.0	16	28	1.10	105
Galena...	5.61	790	410	0	20	68	3.70	181
Galena...	5.61	790	410	1.0	20	62	3.60	175

[a] These values represent filter runs in which the fluid was exhausted from the cell in less than 30 min. In the preparation of charts these values were increased enough to give smooth curves.

Data and Results.—Table 3 shows the results of the preliminary tests mentioned: I should like to point out the reason for the seeming discrepancies in the relative viscosities of some of the muds as shown by these data and those in Mr. Gross' paper. Mr. Gross dry-mixed his suspending agent and weighting materials before adding them to water, while in our work where native mud was used the suspending agent was in the water long before the weighting materials were added, so that the colloidal particles were completely hydrated. When the bentonite and hematite are dry-mixed, soluble salts present in the hematite prevent the proper hydration of the colloidal particles, therefore the viscosity of the resulting mud is much lower than it would normally be.

As these tests were only preliminary, much further study and research should be undertaken before an attempt is made to use such materials in the field.

The foregoing data do indicate that the galena muds have a low viscosity, respond well to chemical treatment, and, still more important, have superior wall-building characteristics. However, I believe the low pH, high conductivity, and rapid settling of the galena muds may offer a considerable obstacle to their use.

G. B. Corless,* Houston, Texas.—What about penetration of filter cakes?

R. C. Marr.—It has been shown that mud solids do not penetrate the formation. The amount of filtrate entering the formation is proportional to the thickness of the filter cake.

P. Weaver,† Houston, Texas (written discussion).—The use of hematite was attempted in the Far East and in Mexico some years ago. In Mexico, in the Concepcion field, hematite was introduced into the well with the drilling mud when the well was already trying to blow out and was producing gas and oil with the returns. It was found that a single cycling of mud containing hematite caused the formation of an extremely viscous emulsion with this oil and gas, and it was impossible to remove the oil and gas or to lower the viscosity so that the fluid could be pumped back into the well.

In the Khaur field, in the Punjab, India, a 28-lb. per gal. mud was used with the hematite as the weighting medium. This field showed the highest pressure ever recorded for the depth and no report was made that any trouble was found in the formation of emulsion, but the formations being drilled contained very little oil and the pressure was mostly hydrostatic.

One question that I should like to have investigated, therefore, would be the effect of galena on the increase of viscosity of the drill mud when oil is present, especially with some gas, because if the result should be similar to that in Mexico it would be a very serious difficulty. Hematite used in this Mexican problem was ordinary commercial red oxide and it is possible that the degree of fineness was greater than in the galena and that the formation of emulsion could have been prevented by using coarser particles. The results were so bad that future operations in the same field were conducted by using blowout preventer and maintaining back pressure instead of by weighting the drill mud with hematite.

H. E. Gross.—While on the subject of India, I might add that since writing my paper I have found a scant reference to some research done by Dr. J. T. Evans on intensive weighting of petroleum drilling muds with galena and sphalerite.[1] The Asiatic Petroleum Corporation of New York City of the Royal Dutch Shell group expressed interest in galena for use abroad.

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[1] Discussion of J. T. Evans: Preparation and Control of Mud Fluid for Pressure Drilling Conditions. *Jnl.* Inst. Petr. Tech. (1937) **23**.

Chapter IV. Petroleum Economics

An Equilibrium Theory of Proration

By Joseph E. Pogue,* Member A.I.M.E.

(New York Meeting, February, 1938)

Any mechanism, either natural or artificial, for regulating the functioning of a given unit in the general economy must operate toward the maintenance of equilibrium if it is to survive. The petroleum industry, concerned as it is with the production of a natural resource of specialized character, is surrounded not only by the economic factors common to other industries but by an extra set of unique elements centering about the fugitive character of crude petroleum under conditions of competitive development. The term equilibrium, therefore, so far as the oil business is concerned, involves a combination of economic and physical factors: the first set having to do with supply, demand, costs, profit margins, purchasing power, and the like; and the second, with underground pressures in oil pools, efficient rates of extraction, and all other aspects of engineering that may be summarized by the familiar term "conservation." The two categories, in fact, are not as clearly divided as the foregoing statement would imply, for in practice it will be found that the economic and physical aspects have a pervasive interaction and interrelationship.

If the development of the petroleum industry in the United States is examined from its inception in 1859 down to the present, it will be found that, beginning about 11 years ago, a new mechanism for regulating the production of crude petroleum made its appearance. Prior to this recent period, the production of this raw material was determined by competitive forces operating without outside restraints. At present the output of crude oil is subjected to supervision by regulatory bodies in most of the oil-producing states, which impose upon the operators certain conditions having to do with the manner and *rates* of production. Thus, in the space of a decade, the mechanism for producing crude oil has changed from an automatic to a designed procedure called proration. And in its short history this method has been marked by a rapid evolution in its nature and incidence, with progressive changes still under way.

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DEVELOPMENT OF PRORATION

Proration developed in response to a serious dislocation between supply and demand. Up to the middle of the last decade, competitive forces operating without restriction were able to maintain an approximate balance between the demand for crude oil and the aggregate *open-flow* production of our oil wells. And while the departures from this form of equilibrium were frequent and sharp, subject to the vagaries of oil-field discovery and fluctuations in the business cycle, balance was always regained after an interval and the system worked, although at the expense of considerable waste. With the perfection of an extraordinary range of new technology and the maturing of the rate of growth in the demand factor, however, the aggregate open-flow capacity of our oil wells expanded beyond the requirements of the market in a manner and to a degree that appeared to be a permanent new relationship. At this juncture a new economic factor became essential to reestablish equilibrium under the new circumstances; and the instrumentality obviously had to be of a kind that would permit the current supply of crude petroleum to be *less* than the open-flow of the totality of oil wells. Thus the Rule of Capture, which had heretofore dictated capacity production—except in a few instances, when unit operation was feasible—had become untenable and a modifying influence made its appearance. Proration, therefore, had its inception as an economic corrective to the Rule of Capture and its acceptance was motivated by the need for a new stabilizing influence. Hence proration came on the scene in response to an economic motive.

Accordingly, it may be said that proration got under way as a stabilization influence in answer to a need for a mechanism less drastic and quicker acting than price. In the presence of divided pool ownership, the unfettered operation of the Rule of Capture, and the impetus of modern technology, price alone had ceased to be a satisfactory control for the maintenance of equilibrium in oil production. For the failure of the price mechanism to function as an effective regulator of supply, two reasons may be adduced: (1) the inability of slow-moving law to offer a substitute for the concept of property peculiar to fugitive minerals—namely, that these substances must be reduced to possession to provide evidence of ownership; and (2) the wide range in costs as between different categories of production, current and ultimate, flush and settled, deep and shallow. The Rule of Capture induces hasty drilling, with its concomitants of inferior utilization of reservoir pressure and the employment of capital in unnecessary wells, the aggregate effects of which are to unsettle underground equilibria and supply-demand balances. Cost amplitude tends to force premature abandonment of high-cost elements of supply under competition with other areas rendered low-cost in the short-term sense by the Rule of Capture, which operates to reduce such costs through the destruction of future values. These two factors, combined, rendered the price mechanism vulnerable in the face of overdiscovery.

Once initiated as a working procedure in loci of overproduction, proration generated the urge and created the "need" for its wider and more permanent establishment. In the first place, its stabilization effects were agreeable and won adherents to the plan, while, by the same token, they encouraged further wildcatting, discovery, and drilling, thus creating additional areas requiring curtailment in the interest of equilibrium. Thus, once under way, proration spread further afield and came under the purview of operators and officials in successive states. To the operator, it made appeal as a stabilization measure and soon the industry reached a position of dependency upon the new instrumentality. To the state official, it claimed interest as a conservation measure, for it created a more orderly production and obviously tended to conserve the gas; and hence the regulatory commission of state after state came to be empowered by law to administer the procedure. Thus, equilibrium—both physical and economic—became a general objective, with a slow but persistent increase in the degree of recognition accorded the physical principles.

After proration reached a condition of wide application and a broad body of experience developed, it became apparent to all concerned that the ultimate recovery of oil and the flowing life of oil fields were increased by virtue of operating wells at reduced capacity; hence proration became firmly entrenched as a conservation measure of importance. It is the conservation aspect of proration, indeed, that enabled its progressive institutionalization as a state-directed practice under the authority of state conservation laws. Proration thus rests upon the principle that the open flow of oil wells is wasteful and disruptive of equilibrium; that the reservoir pressure in an oil pool is a value needing to be conserved and utilized to best advantage. That the beneficiaries of proration continue to think more in terms of its stabilization than its conservation effects, masks but does not hide this principle.

Administration

In the course of the establishment of means for administering proration, the conservation and stabilization aspects of the method became inextricably commingled. The stabilization objective was the motive; the conservation objective, the justification and grounds upon which a legal structure could be reared. Early in the evolution, the regulatory bodies faced the necessity of developing a procedure for determining the degree of curtailment to be imposed, both in respect to specific fields and in the aggregate; and "market demand" was the measure adopted, for by its promise to create economic equilibrium the profit motive was invoked. It may be doubted whether a new system of control could have been constructed on the basis of an abstract conception of conservation, at least not in an atmosphere becoming friendly to regulation for economic objectives; at any rate, a pragmatic course was followed and "market demand" became the controlling yardstick in determining the rate at which the individual well would be permitted to produce. In the presence of a potential supply in excess of demand, this concept provides a means for equating supply and demand, and at the same time gaining the advantages of reduced flow per unit. It sacrifices the attainment of perfect underground equilibrium in the operation of the individual pool to the extent that a balance between supply and demand does not call for a level of output identical with that dictated by the optimum, or most efficient rate; and of course the market-demand concept becomes worthless in the event of a disappearance of surplus capacity. Nevertheless, the market-demand concept is workable and contributes in some degree to the attainment of conservation objectives; it has come, in all events, to be an integral part of the system.

Out of the two primary ingredients—the restricted flow per well which the state has the authority to impose in the interest of conservation, and the requirements of "market demand," to which the system must accommodate itself—the scheme of proration has been constructed. In effect, "market demand" is determined for each state, then subdivided into pool quotas, which in turn are allocated to each lease in direct or modified proportion to the number of wells thereon. Thus demand is prorated to the innumerable points of supply. This procedure involves three tendencies that work in the direction of creating internal disequilibria: (1) established trade channels are rendered too rigid, (2) coordination is difficult in respect to accommodating new discoveries, and (3) the well as the ultimate unit is overemphasized, with the result that the drilling of unnecessary wells is stimulated. The last named consideration could be improved if the lease acreage instead of the number of wells were made the divisor in the allocation formulas adopted; and still greater progress could be attained in proportion to the degree with which the allocations were made to conform to the volume of oil in place under each lease. So long as the lease allowable can be increased by drilling wells in excess of the number required to drain the property at lowest cost, unnecessary wells will be drilled, per-well allowables will narrow unduly, costs will be enhanced, and a source of disequilibrium will be introduced into the system that might carry on to critical and disruptive limits. It is in this area that the practice of proration is mechanically the most imperfect, and here consequently is wide room for improvement. Increasing attention by the industry and the regulatory bodies is coming to be devoted to these elements.

In the use of "market demand" as a yardstick for determining production allowables, a maladjustment in the internal balance of the industry is apt to be created if evidence of demand is taken to be the buyers' indicated requirements instead of the calculated needs of the consumer. At times, owing to speculative movements, or to lagging adjustments to changing economic conditions, or even to undue rigidities in accommodating refinery-yield factors to seasonal changes, buyers of crude oil incline to reflect a demand that gets out of phase with the needs of the consumer markets. In such instances, products stocks become maladjusted and price disparities between crude oil and products tend to develop, creating a disproportionate division of revenue as between the different branches of the industry. When this dislocation is carried too far, political forces may be engendered hostile to proration and inimical to its progress. The remedy for this condition is the substitution of "consumer demand" for "buyers' demand" in determining "market demand." There seems to be some appreciation of the importance of this distinction in the gradual abandonment of buyers' nominations as evidences of demand in favor of the type of evidence supplied by the U. S. Bureau of Mines in its advisory production quotas, which are based upon consumer demand; but the principle doubtless deserves further incorporation into operating procedures. The disequilibria growing out of this phase of market-demand determinations should be carefully distinguished from those arising from the tendency of allocation methods to become too rigid because of overemphasis upon historical factors relating to trade channels: the first has to do with the size of the quotas; the second, with the manner of their geographic allotment. In both cases, the equilibrium concept will provide the criteria essential to an advantageous approach.

Equilibrium Concept

Inasmuch as proration, as practiced, performs a stabilizing function, it becomes important to analyze its objectives in this respect and measure its tendencies in terms of the equilibrium concept. No doubt the popular view of stabilization is that of a condition of profitable price; but legally, and in theory, proration on this score is not concerned with price but merely with the maintenance of a proper balance between supply and demand. It is true, of course, that if proration is applied under circumstances of disequilibrium when prices are subnormal, the price structure will respond with an upward movement; and contrariwise, a lapse in proration, permitting overproduction, will result in a price decline. As both conditions have happened in the past, with the designated price reaction, it is but natural that proration has come to be looked upon in some quarters as primarily a price-fixing measure. Yet it must be clear, upon consideration, that if proration brings about a perfect balance between supply and demand, that action alone has no effect upon price other than to allow it in an orderly manner to seek an equilibrium level; that is, a level responsive to cost, buying power, and the capital requirements of the industry. Inasmuch as cause and effect in respect to these considerations are slow in their incidence, the price structure takes on the characteristic of stability and alterations in it are infrequent. At the same time, price comes to be regarded as a reward for adhering to the proration plan; assumes notoriety as something that can be controlled in the interest of one class or another; and thus, entering into the political arena, becomes the focus of efforts to modify its normal course. These efforts are to be thwarted, if maladjustments are to be avoided. Limited to the maintenance of equilibrium, proration will be on sound ground; but if it moves toward the creation of artificial values instead of merely permitting the emergence of natural values, proration will prove disruptive of equilibrium and violate our definition of the requisite for survival.

Efficient, low-cost production of crude oil obviously requires a larger underground reserve than would be needed to balance demand under rapid, open-flow conditions. Where lands are held in large blocks, as in most foreign fields, this condition tends to be fulfilled automatically and the ideals of unit operation are attained. In the United States, however, the prevailing conditions of land tenure are different: the oil reservoir is usually subdivided into multiple ownership, and the Rule of Capture, if unaffected by collective action, forces a rate of extraction harmful to the most effective utilization of the reservoir energy. In some cases the reservoir is unit-owned; in others, a unit policy is pursued by agreement; but in the large majority of instances, proration is the only influence that operates to create some of the advantages of collective action. If proration, in its further evolution, moves progressively in the direction of conserving reservoir pressure, it will be fulfilling its most important objective; and, contrariwise, any retrogression in this respect will presumptively weaken its tenure. Progress in the direction indicated requires the engagement of increased amounts of capital in the establishment of reserves, so that the aggregate back log of blocked-out oil will be sufficient to sustain production under back pressure. The increased stability brought about by proration encourages the investment of capital, even though the return is delayed, the compensating factor being a reduction in interest rates corresponding to a mitigation in the risks involved; but equilibrium in the capital factors will be upset if the larger reserves needed for efficient operation become too quickly drilled and converted into overcapitalized potentials. From this viewpoint we meet again the problem faced by proration of improving its effect upon drilling rates to the end that there may be a better balance between current production and the "potential" in the presence of larger reserves.

In the development of proration, the state naturally has become the administrative unit. This circumstance permits competition among the states for their respective shares of the national market; and there still remains a wide lack of conformity between these units in respect to regulations and procedures, although the tendency is toward greater uniformity as time goes on. Serious and potentially disruptive disparities have developed in the allowables per well and the ratios of quotas to reserves in contiguous and competing states, and problems of this nature are among the most obdurate occupying a position in the interstate zone. Obviously some measure of coordination between the states is called for in the interest of continuity of equilibrium, and this gap has been filled by two instruments: (1) the advisory state production quotas supplied monthly by the U. S. Bureau of Mines; and (2) the Interstate Oil Compact, designed to provide the states with a means for acting together in oil-conservation matters. The advisory quotas are useful but have the objection as now computed that, being based upon existing trade channels, they do not allow for the flexibility of change in oil movements that is so necessary to avoid internal stresses; while the Interstate Oil Compact, still new, has not as yet adequately directed its labors along the intricate and fundamental lines so necessary to be explored if proration is to be guided into its most effective channels. It should be recognized that if the coordination function is not to reduce the autonomy of the states concerned, these states should prepare themselves to provide the essentials of coordination.

The equilibrium concept of proration here presented, if valid, offers to those concerned with its administration and furtherance a criterion that may be useful in directing the evolution of a procedure that is yet an imperfect instrument. Every phase of proration may be subjected to the test question: Does it contribute or detract from equilibrium? And the answer, perhaps, may throw some slight upon the "desirability" of that phase. In summary, therefore, we may illustrate the point and bring the argument to a close by setting down a series of key questions, as follows:

1. Does proration contribute to the efficient utilization of reservoir energy in the production of crude oil? And is this contribution progressing in the direction of neutralizing the effects of the Rule of Capture through the furtherance of collective action in the single oil pool?

2. Does proration induce a balancing of supply and demand, without in so doing creating other maladjustments that will tend to upset this balance? And in bringing about such a balance, does proration leave price free to express natural values and perform properly its functional duties?

3. Does proration operate to preserve capital equilibrium, so that the proper amount of capital is drawn into the business, but redundant capitalization is avoided?

4. Is proration making adequate advancement toward bringing about a suitable relation between demand and "potential" production? Is not much greater progress needed in changing methods of administration so as to retard the drilling of unnecessary wells? Is proper headway being made toward the institution of allocation formulas and well-spacing patterns designed to preserve equilibrium both in the single reservoir and in the economic structure?

5. Does proration promote sufficient flexibility in trade channels to permit their orderly adjustment to changing requirements, with due regard to relative costs and size of reserves? And are its allocation procedures such as to stimulate orderly development and retard improvident operations?

6. Is proration approaching adequately the problems lying in the sphere of coordination between the oil-producing states? Is the legal instrument devised for this purpose, the Interstate Oil Compact, meeting its responsibilities with sufficient energy and skill to safeguard this field of operation from attachment by a higher central authority?

The mere formulation of these questions may illustrate how the criterion of equilibrium may serve to focus attention upon the development that proration has already attained and the nature and complexity of the problems it still faces. A great American industry is engaged in constructing a new operating form and the outcome of this effort will be of the broadest interest.

What Are the Uneconomic Uses of Petroleum?

By John D. Gill* and E. T. Knight*

(New York Meeting, February, 1938)

Much has been written and said concerning the alleged wasteful and uneconomic use of natural gas and petroleum. Especially condemned has been the use of natural gas for the production of carbon black and the use of heavy fuel oil under steam boilers.[1] The critics of these usages of gas and oil have sought to make effective their verbal attacks on the industry by the repetitive expression of the words "inferior" and "superior" uses[2] of petroleum. Thus, to employ natural gas for residential heating was to use it in a superior way; to use it for the production of carbon black was to use it in a wasteful and uneconomic way. To use petroleum for the production of automotive fuel was to use it in a superior way; to employ it as a residential fuel and as the prime source of power in an industrial plant was to use it in an inferior and uneconomic way.

No doubt the objections to such employment of gaseous and liquid natural hydrocarbons originated in the belief that natural gas and petroleum are limited, nonregenerative mineral resources, and that the functions they perform can be just as well performed by other natural resources like coal,[3] of which practically unlimited reserves are known. The generations that have dominated each of the last four decades have counted reserves[4] of petroleum in terms of a few years supply. Meanwhile, domestic demand for motor fuel rose spectacularly from a few million barrels in 1900 to more than 500,000,000 bbl. last year.[5] The more imaginative and vocal critics drew startling word pictures of the catastrophe of 25,000,000 motor vehicles made useless and of the great automotive manufacturing and allied industries brought to an untimely end, and millions of workers left hopelessly unemployed by what they called the deplorably rapid depletion of the petroleum reserve.

Many of the critics have been sincere advocates of the conservation of natural resources; many others, and in recent years probably the majority, have espoused the doctrine of conservation to promote their own self-interest rather than that of the public. The latest advocate of severe restriction in the use of petroleum for the alleged purpose of conserving the petroleum resource proposes to achieve that end by a bill,[6] now before

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[1] Notes are at the end of the paper.

the Federal House of Representatives, that provides for the levying of a heavy, discriminatory sales tax upon fuel oil.

The absurd and uneconomic proposal to tax heavy fuel oil punitively in order to force a kind of hothouse growth in the yield of motor fuel, and a reduction in the total amount of crude oil required to satisfy the motor-fuel demand, has its humorous aspect. As every oil man knows, the production of motor fuel by cracking petroleum fractions as light as gas oil, and even kerosene, by the most highly developed refinery technique results in the production of heavy fuel. Of the 310,000,000 bbl. of viscous fuel oil produced last year, probably upwards of 150,000,000 bbl.[7] resulted from the cracking of light oils in the manufacture of gasoline.

The present authors take issue with these sincere but irrational conservationists whose concern for the future commands sympathetic and thoughtful consideration, but before attempting to demonstrate the untenable position they occupy wish to make clear that no form of physical waste of our resources that could be practically and commercially avoided is condoned. However, it is important to an understanding of the matter to adopt a sensible view of what is commercially avoidable physical waste. Unless this is done, we shall all find ourselves practicing a penny-wise and pound-foolish policy. We may act as did the Simple Simon on vacation who, steeped in the inhibiting traditions of the virtuous thrift of an earlier economic era, remained in his hotel room to get the full "value" of its high rental when he should have been sightseeing. It is not a far cry from this absurdity to the criticisms of conservationists of the recent past who would have prohibited the production of much needed crude oil because gas produced in association with the oil, lacking a market, was blown into the air[8] or burned in flares.

The conclusion of the present study may be stated unequivocally. Currently, there are no uneconomic uses of petroleum. The resource is being employed as effectively as society, bulwarked by a highly developed technology, can feasibly employ it. There is no suggestion here that technical perfection characterizes the present-day operations of the producing and refining divisions of the industry or the utilization of its products; but, rather, that in the light of present knowledge an approach to practical perfection obtains. Nor is there here any attempt to refute the allegation that many hundreds of millions of barrels[9] of crude petroleum have been produced in excess of the amounts that would have been sufficient for the production of motor fuel and other products intended for so-called "superior" uses had there been available for use in earlier days the technology and equipment now employed by the industry. But it is idle to speculate on what might have been. Better to spend time considering the far-reaching benefits that have accrued to our society from the rapid development of the petroleum resource and the harmful consequences of attempts to restrict the usage of crude petroleum by the uneconomic punitive taxation of an important by-product[10] of the production of motor fuel.

Unquestionably, during the past 25 years, the material welfare of our country has grown more rapidly than in any other period of equal length.[11] Few persons would deny that this spectacular growth has been made possible, in large measure, by the development of automotive transportation.[12] Without abundant and cheap motor fuel, the spectacular growth of motor transport would not have been possible. Support for this statement can be found in a comparison of the development of the automobile in this country, where motor fuel has been cheap, with the development of the use of automotive facilities in countries abroad where the cost of fuel has been high.[13] To the observer it appears that the growth of the material welfare of many countries has paralleled the rapid growth of the motor vehicle. The role played by the "inferior" products in this superb development has been overlooked or ignored by the critics. To see this matter clearly it may be helpful to review a phase of the evolution of the business.

The production of vast quantities of motor fuel was accompanied necessarily by the production of considerable volumes of gas oils and heavy fuel oils, which had to be marketed in order to clear the way for the production of still larger quantities of gasoline. There was no other commercial way. As the knowledge of the industry grew in the nature of its raw material; as suppliers of refinery equipment progressed in the development of materials of construction and in the design of ingenious facilities for the more effective processing of crude oil, higher and higher yields[14] of the most desirable product were obtained. But even while the proportions of the so-called "inferior" products declined, the absolute production[15] of them increased.

Now speculate upon the impediments to the development of this vast industry that would be set up by the taxation of fuel oil sufficiently severe to withhold large quantities of crude petroleum from the use of the present generation, for the possible use of future generations. Speculate, indeed, because the estimation of the harm to our economy resulting from such taxation can be approximated only in the broadest, general terms, as by comparison of the relative growths of the economies of whole countries, already suggested. The tax would have restricted the use of gasoline, hence of the automobile and related industries and thus of a large segment of the economy. Follow through the facts to their implications.

There was a time, not so long ago, when the price of gasoline would have been raised by 3¢ a gallon[16] for every cent of tax upon fuel oil. The reason for this is easily understood. As already stated, fuel oil is produced of necessity when gasoline is produced. It must be sold in competition with other fuels and priced to clear the market of it. Strenuous efforts have been made to have it carry as large a share of the cost of producing and refining crude oil as possible. A study of prices indicates that, in a very substantial way, fuel oil has always brought the highest realizations compatible with its timely disposal. Support of this statement is found in the occasional storage of oil awaiting better prices. It must be clear, then, that any "conservation" of crude effected by a tax on fuel oil would have resulted primarily from restricted use of gasoline. Gasoline users would have had to pay the tax without any benefit whatever accruing to them therefrom.

The plain fact of the matter is that, when uneconomic punitive taxation is levied there is started a train of damaging sequences to which no visible end can be seen. Some of the conservationists might be gratified by any reduction in the consumption of crude oil, overlooking, or ignoring, the enormous benefits to the general economy that have resulted from the rapid development of the resource. By reflecting on this situation one may become better able to perceive and weigh fallacies inherent in many legislative proposals and enactments on business matters. Each economic planner or manipulator with some special interest to serve would "fix" the economy to suit his own ideas, regardless of the losses to the general economy, with which he appears to be little concerned.

The simultaneous rapid development of the petroleum industry, the automotive industry and our general material welfare has been possible under the relatively free, flexible economy that has existed. Certainly such an economy has offered more opportunities for the exercise of initiative and ingenuity than one shot through with punitive legislative tax enactments. Incalculably great benefits have accrued to the people under the former system. Among these is a notable but less obvious benefit conferred on the nation by the very competition that oil has offered other fuels.

The competition of increasing quantities of fuel oil with the anthracite and bituminous coal industries appears to have been a more potent force in increasing the operating efficiency of those industries than any other known economic factor. In the 12 years to 1919, the maximum quantity of fuel oil made available for competition with solid mineral fuels did not exceed the equivalent of 7.5 per cent of the latter.[17] During this time, the operating efficiency of the coal industry, as measured by the output per employee mining bituminous coal, remained nearly stationary. After 1920, the oil industry exhibited remarkable vigor; absolute growth was spectacular; the quantity of fuel oil placed on the market rose with the rapidly increasing demand for motor fuel and, with respect to both the domestic and industrial fuel markets, loomed as a competitor to be reckoned with. It was during the latter period that the coal industry appears to have made its greatest progress technologically. In the 12 years between 1920 and 1931, the output of soft coal per employee rose 32 per cent, from 4.00 tons to 5.30 tons per man per day.

The significance of this natural competition, by which fuel oil indirectly conferred large benefits on the coal-using public, is likely to be overlooked by the man on the street. As a consequence, he is more often than not indifferent to the unsound preachments of the tax advocate who, assuming the role of patriot-conservationist, defends his restriction plan on the ground that petroleum must be saved in the interest of national defense, etc. What is the validity of this latter argument?

Anyone who wishes to restrict the production of crude petroleum for any purpose whatsoever does so in the name of conservation. Only 13,000,000,000 bbl. of known reserves, equal to only 10 years of consumption at the current rate of demand! Only 4 years[18] of assured supply at the present rate of demand, it being well established that perhaps 20 to 30 years would be required to produce all of the proven reserves! So the argument runs. Superficial validity appears in the fact that there is no assurance that, even with the most highly developed prospecting methods, petroleum will be discovered in quantities sufficient to satisfy the increasing demand for motor fuels and the rapidly growing and socially beneficial demand for domestic heating oils.[19]

The present authors have no inclination to meet this "Wolf! Wolf!" cry with the plausible argument that while the industry has been listening to similar cries for more than 30 years it has been discovering and producing enough oil to satisfy a growing demand during that time; has now the largest proven reserve of its 80 years of experience; and that there are reasons to expect it to continue to satisfy demand[20] for some indefinite time. Rather, it is suggested that an examination be made of the facts to determine what difference it really makes whether the supply will last only 10 years or, by rigorous restrictions on the use of known reserves, 15 or, perhaps, 20 years.

On one phase of this matter, there should be unanimity of opinion. Our country cannot afford to retard its peacetime economic development by restricting the use of products that have proved themselves essential to that development. The problem of maintaining the tempo of development cannot be solved by uneconomic restraints on consumption of products exemplified by domestic heating oils, but it can be solved by preparation for the production of supplementary supplies of gaseous and liquid hydrocarbons anent the day when the depletion of the petroleum resource naturally restricts the consumption of petroleum products.

Such developments are in progress; probably the reason that they are not more in evidence is that their potential results are not yet needed. Depletion of the petroleum reserve is not in sight. The conservationists might take courage in this fact and find its substantiation in the willingness of practical oil men to maintain and expand investments,[21] totaling billions of dollars, for the transportation, refining and marketing of petroleum products.

Moreover, those conservationists that have a predilection for solid mineral fuels might gain comfort from a review of historical instances[22] of reversals of economic trends and thereby see in the early depletion of the petroleum resource the opportunity for a mammoth expansion of the coal industry. Support is not lacking for the belief that vast quantities of gaseous and liquid hydrocarbons are yet to be produced from coal.[23] Adoption of this view might lead these interests to conceive a constructive policy for action in behalf of their own industry, which would insure an adequate supply of liquid fuels when the petroleum resource is exhausted.

Perhaps, second to heavy fuel oil, no other product or process has been the subject of so much adverse criticism as that by which carbon black is produced from natural gas. Over a period of many years, the production of carbon black has accounted for the consumption of thousands of billions of cubic feet of natural gas. Gas for this purpose has yielded a lower realization than has that employed for any other of the reported uses.[24] Perhaps it was this fact that led to condemnation of the production of carbon black by the incomplete combustion of natural gas. The use of the latter in distant cities for domestic purposes has been hailed as a more appropriate[25] employment of its concentrated fuel value and regulative quality.

But, here again, it seems to the present writers that this view is the result of an incomplete analysis of the situation. Its proponents have not gone much beyond the making of comparisons of the market price of natural gas employed for the production of carbon black with the price that the gas might have brought under other circumstances. They have stated that carbon black was unreasonably cheap because of the uneconomic employment of gas for its production.

They have not seen the practical impossibility of carrying gas to distant markets because heavy investments in pipe lines could not be justified in the face of uncertainty regarding the extent of reserves. And, if they had looked beyond the obvious phase of the matter to the value to the public of carbon black, they would have discovered several important facts—namely, that its chief function is as a reinforcing agent in the treads of automobile tires, "that it provides toughness that enables the tread to stand the abrasive action of contact with the road, that no other substance known today can approach in utility the record of carbon black for this purpose, and that a conservative estimate of the usefulness of carbon black in tire treads indicates that tires made with it last from two and a half to three times as long as tires made with the next most suitable material."[26] Conservatively, it may be stated that, over the last 15 years, the saving to the public in the form of longer-life tires has been upward of 40 times as much as the value of natural gas employed for the production of all carbon black manufactured in this country for whatever purpose, even when valued at the well at the average price realized for natural gas from the same source put into the domestic market.[27]

Consider briefly a closely related subject. Some sincere conservationists, possessed of patriotism of a sort, have deplored the export of our petroleum. There is no doubt about it, the cumulative quantity shipped abroad has been very large. During the past 37 years, the value of our petroleum exports has exceeded $9,000,000,000.[28] It is pointed out that some day our country may just as direly need the equivalent of the oil exported as it may need that oil now used domestically in so-called "inferior" ways.

Here again, the lack of complete analysis tends to cause the essential facts to be overlooked. These overseas transactions do not represent a trading of our heritage for a mess of foreign pottage. Economically, the export of oil can be fully justified on the ground that it enabled us to purchase from abroad vast quantities of products not obtainable in our own country, which were absolutely essential to our comfort and development. In a general way, they represented intelligently directed economic efforts, most likely to advance our standard of living.

It is hoped that what has already been stated has established the bases for dissociating unsound implications from the meanings of the terms "inferior" and "superior" as applied to certain fractions of petroleum. To say the least, these terms are difficult to define. Nor is the classification of products simplified by an attempt to ascertain and compare intrinsic values. Moreover, in an economic sense, classification and definition according to market values are not wholly satisfactory. Shin bone and liver must be produced with tenderloin. Similarly, even though to a different degree, heavy fuel oil must be produced with gasoline. Clearly, the terms "intrinsic" and "market" are not interchangeable; indeed, they are not strictly comparable. For example, the commercial value placed upon a long, high-speed subway ride in New York may be 5¢; a ride of half that distance with less speed in Washington may cost twice as much. The "intrinsic" value of the cheaper ride may be the greater.

The conclusion of this study—that currently there are no uneconomic uses for petroleum—can be supported by detailed technical analysis; but it finds its broadest and firmest foundations in those economic analyses that comprehend all of the important interrelated factors of the economy. A product and the process of its production are to be viewed as economic when they elevate the total material welfare by a greater measure than would be effected by the expenditure of the same amount of energy in some other direction. True, the measurement of comparative benefits resulting from the expenditure of a given amount of energy in two or more directions presents the student of the subject with a problem of vast magnitude. No doubt this is the reason why some of the thinking about "inferior" and "superior" and "economic" and "uneconomic" uses of petroleum has stopped short of sound conclusions. It illustrates, perhaps as well as any other circumstance, the fundamental fact that the advancement of the economic welfare requires freedom for the exercise of initiative by multitudes of men. It shows also that conservation is not tantamount to a hoarding of resources but, rather, that true conservation furthers material welfare by permitting the usage of resources in accordance with the best information of the time. Better to use now what we have, in the way that seems best to many informed minds, than to save for we know not what.

NOTES

1. In Quinton Relief Oil and Gas Co. vs. Oklahoma Corporation Commission, burning of natural gas to manufacture carbon black was prohibited in the interest of preserving the gas for domestic and industrial heating purposes although this retarded realization of its value.

"Oil burning should not be permitted in stationary steam boilers . . . because oil constitutes a particularly high-grade and convenient form of fuel without which automotive operations would be impossible . . . because there is only a limited amount of this high-grade form of fuel . . . because steam plants utilize fuel extremely inefficiently."—The Economic Utilization of Liquid Fuel, 20.

2. " . . . not even half of our present production of crude oil is required to supply our national petroleum demands for recognized superior uses . . . the products thrown into inferior uses contain at least 50 per cent of easily obtained gasoline and other superior derivatives."—Federal Oil Conservation Board (Feb. 1926) 153.

3. "Reserves of bituminous, sub-bituminous and semi-bituminous coal in the United States, within 3000 feet of the surface, amount to nearly 2.5 trillion tons and would yield about 92 billion barrels of motor fuel."—Federal Oil Conservation Board (Jan. 1928) 5.

4. Petroleum reserves, United States, as follows:

MILLIONS OF BARRELS

Date	Authority	Quantity Estimated	Quantity Actually Produced Subsequent to Estimate
1908	David T. Day, U. S. Geological Survey	8,014[b]	17,980
1915	U. S. Geological Survey	7,500	16,349
1925	Committee of Eleven, Amer. Petr. Inst.	5,321	11,296
1937[a]	Petroleum Facts and Figures, Amer. Petr. Inst.	13,063	1,278
1938[a]	*Oil and Gas Journal*	13,489	
1938	Amer. Petr. Inst. (recently released)	15,507	

[a] As of Jan. 1 of year indicated.

[b] Minimum; maximum, 22,514.

5. Indicated demand of motor fuel in United States has been:

THOUSANDS OF BARRELS (42 GALLONS)

YEAR	QUANTITY
1899	6,685[a]
1910	12,865[a]
1920	108,945
1930	397,770
1937	518,760

[a] Production of naphtha and gasolines as reported by Census of Manufactures.

6. Sponsored by Representative Boland of Pennsylvania—1¢ per gallon equal to about 35 per cent on wholesale price.

7. During 1937, there were run through cracking stills 533 million barrels of stock for a yield estimated at 30 per cent.

8. In the case of Ohio Oil Co. vs. Indiana—" . . . providing that it should be unlawful to permit the flow of gas or oil from a well to escape into the open air. . . . "

9. Production:

FROM 1916 TO 1930	THOUSANDS OF BARRELS
Gasoline produced from crude	2,972,777
Crude required @ 44.2 per cent yield	6,724,400
Crude actually run to stills	9,019,079
Indicated saving in crude requirements	2,294,679

10. Gas and fuel oil, 1937, represented 38.6 per cent of volume of crude processed and supplied 21.8 per cent of total refinery value of products.

11. Real wages increased the equivalent of 28 per cent of the 1913 standard between 1910 and 1936. No other two years, 25 years apart yet both showing profitably active business, have been marked by a gain in real income even approaching this magnitude.

12. In 1900, automotive and allied industries contributed negligibly to national income. Currently, their activity represents about 20 per cent of all retail purchases.—Bureau of the Census.

13. National economic welfare and its relation to concentration and use of automobiles, and the price of motor fuel, cannot be shown satisfactorily in the few statistics like the following selected data because of complex factors, for example, age of country,

Country	National Income (Produced) per Capita . 1932	Population per Motor Vehicle, 1932, Per Cent	Price of Gasoline End of Year 1932, Cents per Gal.	Population per Motor Vehicle, 1936, Per Cent	Price of Gasoline, July 1937, Cents per Gal.
United States	$384	5.0	17.6	4.5	19.3
Canada	307	9.3	22.5	9.0	21.4
United Kingdom	253	25.0	22.2	21.0	33.6
New Zealand	207	8.0	29.5	7.0	33.0
Australia	178	12.0	22.8	10.0	30.0
France	193	22.0	28.0	19.0	34.5
Germany	170	101.0	33.3	49.0	59.6
Denmark	165	30.0	20.8	27.0	25.0

area per capita, concentration of population in cities, highway development, extent and development of national resources, etc.

14. Principal petroleum products yielded from crude run:[a]

AVERAGE PERCENTAGE FOR THE UNITED STATES

Year	Gasoline	Kerosene	Gas and Fuel Oils	Lubricating Oil
1899[b]	12.9	57.6	14.0	9.1
1909[b]	10.7	33.0	33.6	10.7
1919	25.2	15.4	50.2	5.6
1929	39.3	5.7	45.5	3.5
1937	43.9	5.5	38.6	3.0

[a] U. S. Bureau of Mines. [b] Census of Manufactures.

15. Production of gas and fuel oils in United States:[a]

THOUSANDS OF BARRELS (42 GAL.)

1919	181,602
1929	448,949
1937	456,867

[a] U. S. Bureau of Mines.

16. In 1909, the yield of gas and fuel oils was 33.6 per cent; the yield of gasoline, 10.7 per cent; the ratio, 3.2 to 1.

17. According to the Bureau of Mines, in 1919, the heating value of hard and soft coal produced totaled 14,602 trillion B.t.u.; the equivalent heating value of gas and fuel oils produced in that year was 1089 trillion B.t.u., equal to 7.5 per cent of the coal calorific value.

18. The President of the United States to the House Ways and Means Committee, Feb. 7, 1938. " . . . there is a possibility of shortage of domestic petroleum in the United States as early as 1940 and a probability of a considerable shortage by 1945."—Snider and Brooks: *Bull.* Amer. Assn. Petr. Geol. (Jan. 1936).

19. Domestic heating oil burners and oil consumed, United States:[a]

Year	Burners Operating at End of Year	Heating Oils Consumed, Thousands of Barrels
1922	56,800	1,762
1925	177,400	8,010
1928	322,000	14,272
1931	760,800	24,659
1933	920,300	35,190
1936	1,352,700	60,178

[a] Petroleum Facts and Figures, Amer. Petr. Inst. (1937) 36.

20. Likely area estimated at 650 million acres still unexplored. Practical well depth now exceeds two miles. Recovery increased 60 to 100 per cent by modern methods.

21. As of 1934, net investment domestically for petroleum transportation, refining and marketing estimated at 4280 million dollars.

22. Production of lumber, ship construction, electric railway revenues, kerosene and, notably, demand for gasoline, which once was a drug on the market.

23. See Note 3.

24. During the nine years from 1927, inclusive, the well price of gas used for the manufacture of carbon black varied from a little below 2.8¢ to 1.57¢. The average well price of gas for all other purposes varied from 8.90¢ to 5.80¢. In general, the latter realizations were about three times the former.

25. See Note 1.

26. Judgment of rubber industry technicians.

27. Between 1922 and 1936, inclusive, 2,745,540 million cubic feet of natural gas were consumed in manufacture of carbon black valued actually at 65 million dollars, but here assumed to be worth $232,820,000 when employed domestically. During this period, the wholesale value of the United States production of pneumatic casings and other tires totaled $7,397,910,000. It was the latter value that was enhanced two and a half to three times by carbon black.

28. Value of U. S. petroleum and refined oils exported:

Year	Thousands of Dollars
1900–1904	$ 369,129
1905–1909	469,417
1910–1914	613,831
1915–1919	1,209,018
1920–1924	2,085,355
1925–1929	2,599,160
1930–1934	1,400,683
1935–1936	511,172
Total (1900–1936)	$9,257,765

Market Behavior of Oil Shares from 1932 to 1937

By Norman D. Fitz Gerald,* Junior Member A.I.M.E.

(New York Meeting, February, 1938)

The purpose of this paper is to analyze the behavior of oil securities during the six-year period January 1932 through December 1937. This period was selected because of its varied character. It includes the depths of the depression, the broad and spasmodic recovery, and the recession collapse. The first part of the analysis is devoted to the correlation of a number of economic factors with an index of 13 oil stocks. The second part is a comparison of the differential behavior of 6 oil stocks. The relationships developed here are only a few of many that might be considered in a complete analysis.

The stock market is regarded as a barometer of business confidence and as such exerts an important influence upon corporate policies, particularly upon industrial expansion. The complex and continuously changing nature of its price structure, the ebb and flow of influences and the effects of impacts require dynamic rather than static analysis. When treated in this way, many of the important fluctuations in market prices and changes in the relationships between securities appear quite logical.

The market for oil securities has varied widely in recent years. The Standard Statistics index of 13 oil stocks made a bull market peak of 166.7 in September 1929. The collapse of the boom and the ensuing bear market finally carried the index down to a low of 36.4 in June 1932. From this point oil stocks made an irregular recovery; they reached a top at 139.7 in March 1937, and after maintaining this approximate level through August, declined precipitously to 93.3 in December 1937.

The prices of these 13 oil stocks have gone up and down under the influence of numberless variables. These variables are of two kinds, those external to the industry, and those that are solely due to its internal condition. The external factors are political, social, and economic, both domestic and foreign. These are the influences that induce the ebb and flow of all prices in general and security prices in particular. Among the internal factors are the regulation of industry, the development of new reserves and processes, and the disequilibrium due to lack of balance between supply and demand. Some of the simpler relationships are examined in this paper.

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Correlation of Economic Factors with Oil-stock Prices

In Fig. 1 are shown the index of 13 oil stocks and certain key elements in the petroleum economy, the price of 36° Mid-Continent crude oil, the daily rate of crude-oil production, and the spot price of third-grade gasoline at Tulsa, for the period January 1932 through December 1937.

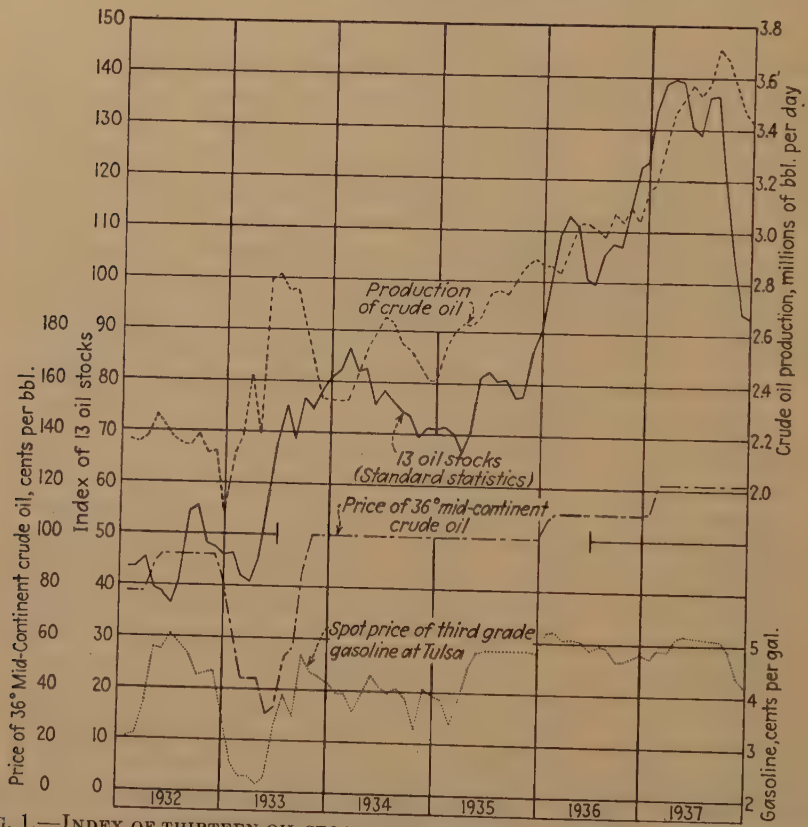

Fig. 1.—Index of thirteen oil stocks, production of crude oil, prices of crude oil and gasoline (monthly, 1932–1937).

These six years have seen substantial changes within our economic structure, especially within the oil industry. All of the series exhibit a general upward tendency from the beginning of the period to the end, as shown in Table 1.

Table 1.—*Advance of Key Factors in Six Years*

	Per Cent
13 oil stocks, prices	120.3
36° Mid-Continent crude oil, price	58.4
Production of crude oil, daily rate	58.2
Third-grade gasoline at Tulsa, price	38.6

The prices of oil stocks are influenced in some degree by these factors. During most of the period the price of crude oil was stabilized and therefore shows but little relationship to the index of 13 oil stocks. The price of gasoline fluctuated with greater freedom than that of crude oil, but during part of the period also was under artificial influences. The relationship between gasoline prices and oil stocks is poor. The trends and fluctuations in crude-oil production and oil stocks show some similarities, but the correlation is by no means good. These factors, while of major importance to the industry, did not control the prices of oil securities in this six-year period. An explanation of changes in stock prices must be sought elsewhere.

There are several ways of examining the relationships between time series. One is to compare their similarity and divergence directly on the time axis, as in Fig. 1. This is fairly simple for short series, but rapidly becomes impracticable with long series, wide fluctuations, and nonlinear functions. Another method is to plot one variable against the other on a scatter diagram, and in this way eliminate the time scale. The consideration of scatter diagrams involves the estimation of simple or complex functions from the grouping of points about a line or curve. The longer the series and the wider the fluctuations, the more accurately the true relationship can be determined.

The joint consideration of price and production of crude oil in analyzing the market appraisal of oil securities should yield better results than separate consideration. The approximate value of crude-oil output has been estimated as production multiplied by the price of 36° Mid-Continent crude oil. This is compared with the index of 13 oil stocks in Fig. 2. The best linear representation of the data has been determined by the method of least squares, and is shown in the figure. The relationship is fair, having a coefficient of correlation of +0.88.

The value of refinery output was compared with the index of 13 oil stocks. The approximate value of the products recovered at the refinery from a barrel of 36° Mid-Continent crude oil was multiplied by the crude run to stills. The relationship of this realization of refiners and the index of 13 oil stocks is shown in Fig. 3. The coefficient of correlation is +0.88, identical with the value of crude-oil output in explaining oil-stock price movements.

It is reasonable for the prices of oil stocks to go up or down with general economic conditions. Petroleum lubricants, fuel oils and motor fuels are widely used throughout industry. The commercial uses of petroleum products are sensitive to changes in business, while the consumption of motor fuel and furnace oil by the general public is slower to respond. Therefore changes in industrial activity can be translated in terms of changes in the demand for petroleum. In Fig. 4, the relationship between the Federal Reserve Board Index of Industrial Production and

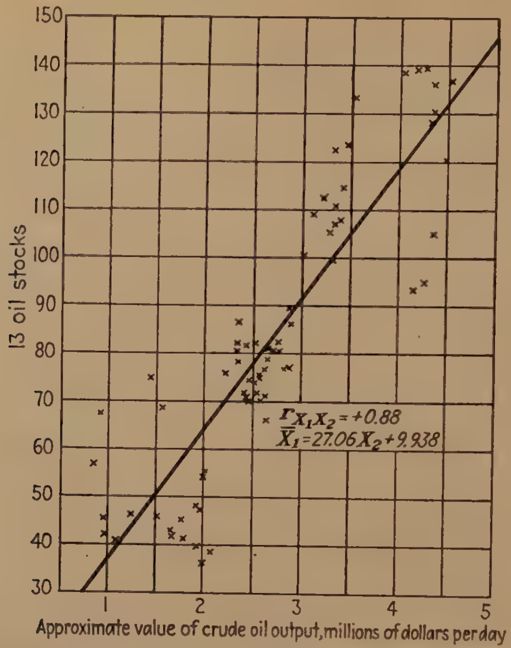

FIG. 2.—RELATIONSHIP OF THIRTEEN OIL STOCKS TO THE APPROXIMATE VALUE OF CRUDE-OIL OUTPUT (MONTHLY, 1932–1937).

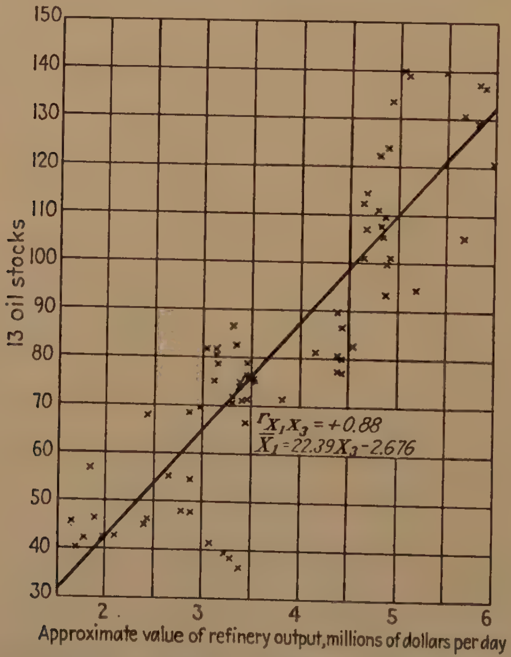

FIG. 3.—RELATIONSHIP OF THIRTEEN OIL STOCKS TO THE APPROXIMATE VALUE OF REFINERY OUTPUT (MONTHLY, 1932–1937).

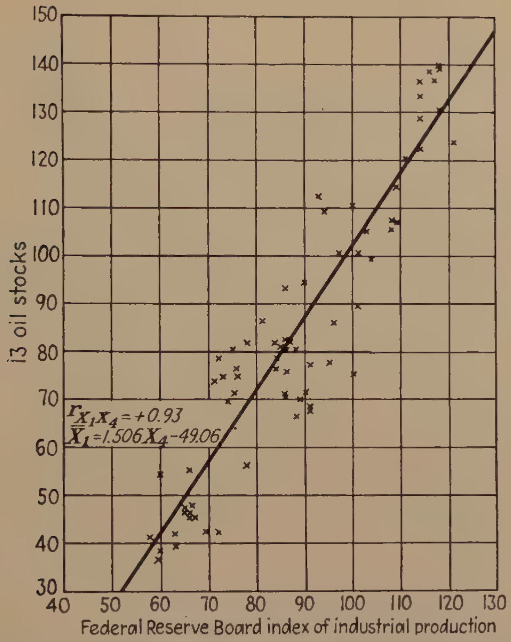

FIG. 4.—RELATIONSHIP OF THIRTEEN OIL STOCKS TO THE FEDERAL RESERVE BOARD INDEX OF INDUSTRIAL PRODUCTION (MONTHLY, 1932–1937).

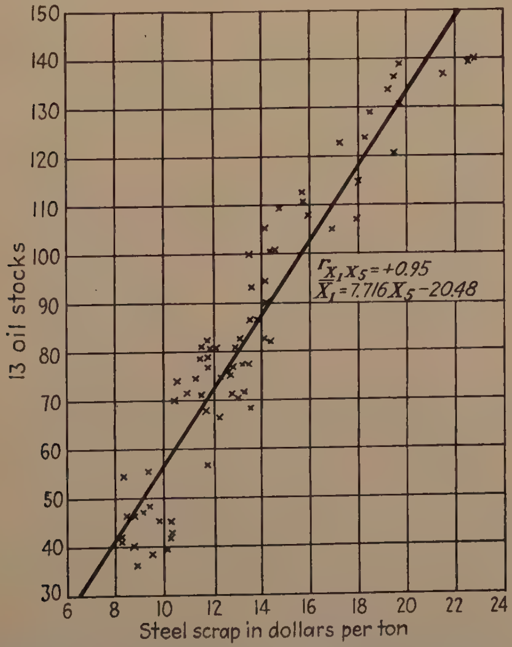

FIG. 5.—RELATIONSHIP OF THIRTEEN OIL STOCKS TO THE PRICE OF HEAVY MELTING STEEL SCRAP AT PITTSBURGH (MONTHLY, 1932–1937).

the index of 13 oil stocks is shown to be very close. The coefficient of correlation is +0.93.

The price of scrap steel fluctuates with business conditions and with the prices of oil stocks. The demand for scrap steel rises and falls with the operations of the steel industry. These in turn are a measure of the expansion or contraction of general business. The relationship between the price of heavy melting steel scrap at Pittsburgh and the index of 13 oil stocks is shown, in Fig. 5, to be very good. The coefficient of correlation is +0.95. There is one obvious advantage in watching commodity prices for clues to industrial conditions, instead of waiting for indices of business activity. Prices are always available currently, while especially at critical times the operating statistics of business are delayed and revisions in the early figures are frequent.

The movement of oil stocks compared with industrial shares in general is quite similar, as is well known. Throughout the period, from low prices to high prices, the variation has been almost point for point, a behavior that is characteristic of an expanding industry in a growing country. The coefficient of correlation of 13 oil stocks with 347 industrial stocks is +0.98.

The earnings of the oil industry and the prices of its securities are influenced in an important degree by such internal factors as the value of crude-oil production and the value of the output of refineries. An examination of the relationships of these factors to oil-stock prices by the correlation method has revealed their influence. When analysis was extended to certain major economic factors external to the oil industry, it was found that during the period considered the index of 13 oil stocks was more closely associated with these external factors than to the oil-industry factors. The results of the correlations are shown in Table 2.

TABLE 2.—*Relation of Index of Oil Stocks to Economic Factors*

Factors	Coefficients of Correlation	Equations of Relationships
Internal:		
Approximate value of crude-oil output.........	+0.88	$\bar{X}_1 = 27.06X_2 + 9.938$
Approximate value of output of refineries.......	+0.88	$\bar{X}_1 = 22.39X_3 - 2.676$
External:		
FRB index of industrial production............	+0.93	$\bar{X}_1 = 1.506X_4 - 49.06$
Price of heavy melting steel scrap at Pittsburgh	+0.95	$\bar{X}_1 = 7.716X_5 - 20.48$
347 industrial stocks..........................	+0.98	$\bar{X}_1 = 0.8600X_6 + 5.00$

DIFFERENTIAL MOVEMENTS OF OIL STOCKS

The index of 13 oil stocks advanced and declined during the six years largely in association with factors external to the oil industry. This is not as true of the individual issues, for many oil securities have moved away from the average of the group. The comparison of differential movements of oil stocks has been limited to six issues. These are the six common stocks included in the Standard Statistics index of 13 oil stocks, for which quarterly earnings are available.

The deviations of these stocks from the average may be due to conditions internal or external to the particular companies. The internal condition of the industry is changing continuously, favoring the production, pipe line, refining, jobbing, and marketing divisions of the industry in varying degrees from time to time. The incidence of these oscillations of fortune upon the economic balance of the different companies alters their earning power and capacity to pay dividends.

The prices of the six oil stocks under consideration have fluctuated over a wide range in the past six years. The closing prices at the end of each of the 25 quarters, from Dec. 31, 1931 to Dec. 31, 1937, were tabulated for analysis. The shares of Standard Oil of California and Continental both closed the period at $29, although the former started at $25, and the latter at $6. In spite of such divergences, there are very evident similarities of trends, and fluctuations.

The analysis of divergence is facilitated by the removal of similarities from the series. These stocks have been under three major influences—those affecting the market as a whole, those associated primarily with the oil business, and those originating in the competitive positions of the companies. The two groups of influences external to the companies can be removed from these series in a large measure by expressing each price in per cent of the sum. In this way six new series were derived, which no longer have similar trends or fluctuations, but display marked individualities and dispersion from the average. The data have been adjusted to Dec. 31, 1931 = 100 and are shown in Fig. 6. The changing price of each share is indicated in terms of the price of the group. For example, at the close of the period, the sum had actually advanced from 100 to 204; while Shell Union had advanced from 100 to 269. Therefore the closing price of Shell Union was approximately (269) (2.04) = 550 per cent of the price at the beginning of the period. The persistent declines of Standard Oil of California and Union Oil of California are in sharp contrast to the vigorous uptrends of Continental starting in 1933 and Shell Union starting in 1935. The movement of Atlantic Refining was characterized by a rally in 1932, eventually canceled by the close of the period. Ohio Oil enjoyed a rally, dip, and recovery from 1932 to 1933; a decline extending into 1936, followed by a rally into 1937.

Several influences may generate this dispersion—the changes internal to the companies and the effects of developments within the industry upon the various units. There is no simple way in which these can be measured, although undoubtedly they are reflected in earnings and dividends. The comparison of earnings and dividend records is complicated during part of this period because some of the companies operated at deficits and paid no dividends. Under normal conditions, changes in earnings frequently are a measure of changes in prices, but this technique is not applicable to deficits.

Earnings are an important influence on stock prices while deficits are not as significant. Earnings roughly measure the capital employed; there is, however, only the vaguest relationship between deficits and the size of the business. Stock prices are free to fluctuate with earnings but not with deficits, for zero is the limit. The movement of stock prices in response to earnings is unimpeded; on the other hand, responses to deficits or very low earnings are usually restricted by the presence of residual or salvage value, if not potential income. Deficits cannot be regarded simply as negative earnings, they must be considered qualitatively in analyzing stock prices. Deficits impair the working capital position of a company and its credit rating. They have a persistent depressing effect

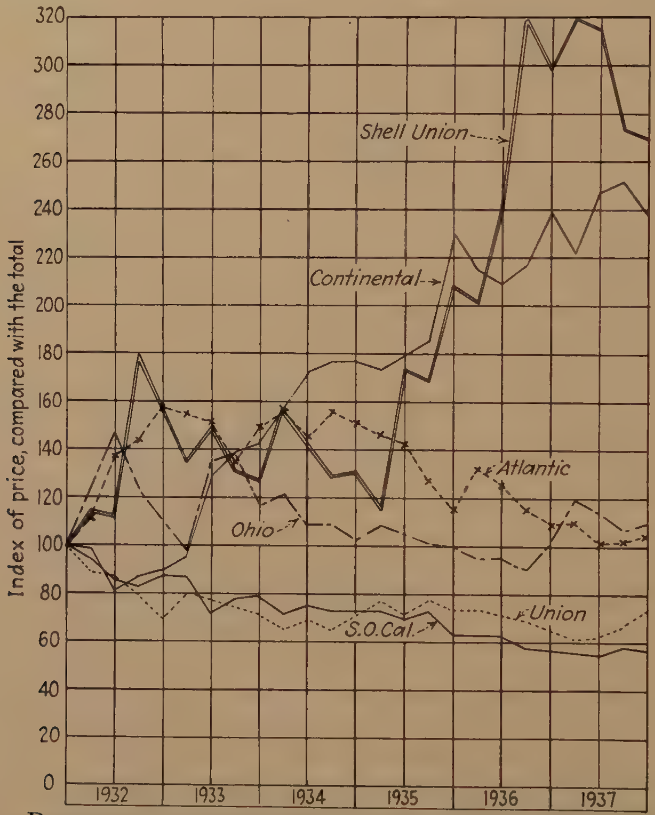

FIG. 6.—DISPERSION OF PRICES OF SIX OIL STOCKS IN RELATION TO THEIR SUM BY QUARTERS, BASED ON DEC. 31, 1931 = 100 (ENDS OF QUARTERS DEC. 31, 1931 TO DEC. 31, 1937).

on prices because they may reduce the efficiency of operations and defer the resumption of dividend payments.

Relative annual earnings, as reported, have been computed by the method used on stock prices. For comparative purposes deficits have been considered as zero earnings. The series is shown in Fig. 7. Standard Oil of California displays a downward trend with the exception of 1934, and Union Oil of California with the exception of 1935. The sharp advances in Continental and Shell Union are again obvious. In connection with the latter the relationship extends even to the reversal of trends in 1937. The general similarities of movement in relative prices of Atlantic Refining and Ohio Oil are reflected in the relative earnings comparison. It should be kept in mind that in the early years of the period earnings were quite erratic and deficits frequent, and throughout the period the figures are subject to changes in the accounting policies of the companies.

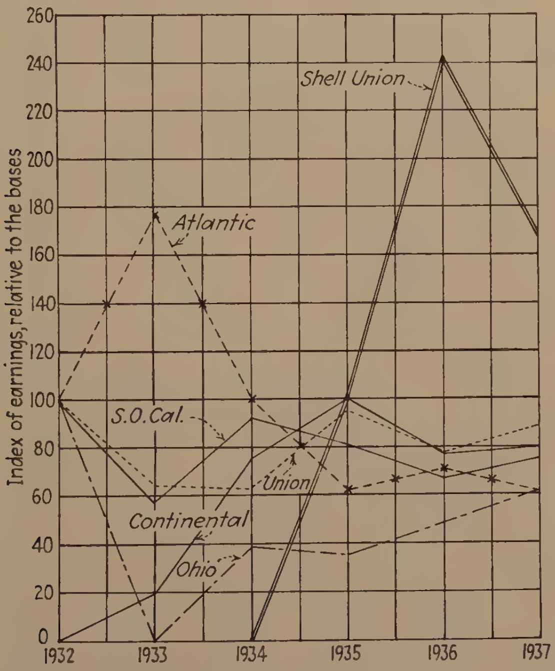

FIG. 7.—DISPERSION OF ANNUAL EARNINGS (DEFICITS NOT CONSIDERED) ON SIX OIL STOCKS IN RELATION TO THEIR SUM BY YEARS, BASED ON 1932 = 100 FOR COMPANIES EARNING IN THAT YEAR, OTHERS BASED ON 1935 = 100 (ANNUALLY 1932–1937).

The earnings of a company are of interest because eventually they may develop into dividends. Dividend payments, as well as earnings, have an influence on the market prices of securities. Relative dividend payments have been computed by the same method as stock prices and earnings and are shown in Fig. 8. The same general tendencies are present in dividends as in earnings, although there appears to be a definite improvement in the details of the relationship with price, particularly for Standard Oil of California and Atlantic Refining. The resumption of dividend payments by Shell Union and Continental were undoubtedly of importance to the stocks of these companies.

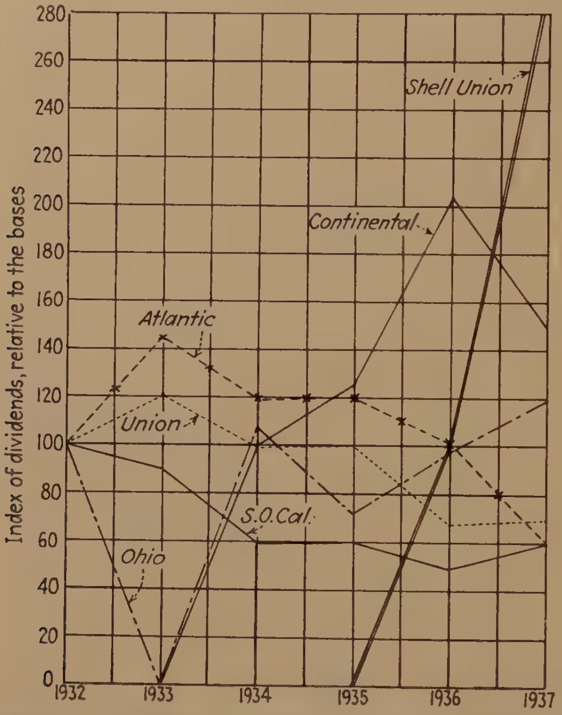

FIG. 8.—DISPERSION OF ANNUAL DIVIDEND PAYMENTS ON SIX OIL STOCKS IN RELATION TO THEIR SUM BY YEARS, BASED ON YEAR OF FIRST PAYMENT = 100 (ANNUALLY 1932–1937).

SUMMARY

Economic factors external to the oil industry appear to have been of major importance in the movement of oil-stock prices as a group in the past six years. This behavior is characteristic of the securities of an industry that serves a diversity of industrial and consumer requirements and is maintaining its competitive position.

Analysis of the prices of shares making up the index reveals important differential movements. These seem to be related to developments within the companies and to the effects of changing internal conditions of the oil industry upon the particular enterprises as reflected in their earnings and dividends.

SOURCES OF DATA

Index of 13 Oil Stocks: Standard Statistics.

Price of 36° Mid-Continent Crude Oil: N.P.N. Oil Price Handbook.

Spot Price of Third-grade Gasoline at Tulsa: N.P.N. Oil Price Handbook.

Production of Crude Oil: U. S. Bureau of Mines, Monthly Petroleum Statement.

Approximate Value of Refinery Output: Computed from data of the U. S. Bureau of Mines and N.P.N. Oil Price Handbook.

Federal Reserve Board Index of Industrial Production: Survey of Current Business.

Price of Heavy Melting Steel Scrap at Pittsburgh: Metal Statistics, American Metal Market.

Index of 348 Industrial Stocks: Standard Statistics.

World Consumption of Petroleum Products and Related Fuels

By V. R. Garfias* and R. V. Whetsel,* Members A.I.M.E., and J. W. Ristori*

(New York Meeting, February, 1938)

Preliminary estimates indicate that world consumption of petroleum products and related fuels in 1937 shattered previous records with a figure of 1,920,000,000 bbl.; that is, 124,000,000 bbl. more than the 1936 total.

The writers, as in previous years, have been unable to account for all the available supply in 1937. This "unaccounted-for" supply, which formerly was thought to go largely into storage in foreign countries, was close to 53,000,000 bbl. in 1933; 93,000,000 in 1934; 111,000,000 in 1935; 75,000,000 in 1936 and 148,000,000 in 1937. As this discrepancy between supply and demand continued year after year, it became evident that other reasons than additional foreign stocks were responsible for it.

It can now be stated that the "unaccounted-for" supply (see Table 1) goes to take care of: (1) consumption of petroleum products and related fuels for military purposes, the figures of which have been and are kept confidential by foreign countries, (2) additions to stocks to be consumed for military and nonmilitary purposes in foreign countries on which likewise no information is available, (3) errors incurred in the conversion of figures of production of crude oil, its products and related fuels from "weight" units, as used in Russia, for instance, to their American or "volume" equivalents and vice versa, and (4) to the lack of reliable statistics on production and consumption, particularly from Russia, the

Table 1.—*World Production and Consumption of Crude Oil, Petroleum Products and Related Fuels*

Thousands of Barrels

Year	Production of Crude Oil and Related Fuels	Consumption of Petroleum Products and Related Fuels	Excess Production over Consumption			United States		Military Consumption and Storage Outside U.S.A.
			United States	Outside United States	World Total	Excess Exports over Imports	To Storage	
1932	1,362,039	1,348,407	R13,011	26,643	13,632	28,781	R41,792	55,424
1933	1,467,128	1,406,923	67,427	R7,222	60,205	60,254	7,173	53,032
1934	1,562,834	1,507,599	26,164	29,071	55,235	64,013	R37,849	93,084
1935	1,702,793	1,614,475	53,027	35,291	88,318	75,474	R22,447	110,765
1936	1,864,997	1,795,560	52,209	17,228	69,437	74,890	R22,685	74,894
1937	2,109,820	1,919,500	161,100	29,220	190,320	119,000	42,100	148,220

Manuscript received at the office of the Institute Feb. 12, 1938.

* Cities Service Co., New York, N. Y.

second largest producer and consumer. The writers are presenting a paper on world consumption of petroleum and related fuels for military purposes, in which an effort is made to analyze the magnitude of this consumption.*

TABLE 2.—*World Production of Crude Oil and Related Fuels*

THOUSANDS OF BARRELS

Country	1936			1937		
	Crude Oil	Related Fuels	Total	Crude Oil	Related Fuels	Total
United States	1,099,687	45,272	1,144,959	1,278,000	51,000	1,329,000
Russia	199,636	1,000	200,636	200,000	1,000	201,000
Venezuela	155,271	800	156,071	185,300	900	186,200
Iran	61,929	900	62,829	78,100	1,000	79,100
Netherlands Indies	47,962	1,800	49,762	54,900	1,900	56,800
Rumania	63,533	1,000	64,533	52,000	800	52,800
Mexico	41,166	800	41,966	46,700	900	47,600
Iraq	29,913		29,913	30,700		30,700
Colombia	18,756	500	19,256	20,200	600	20,800
Peru	17,593	1,300	18,893	17,700	1,300	19,000
Trinidad	13,237	100	13,337	15,600	120	15,720
Argentina	15,458	400	15,858	15,300	400	15,700
British India	9,566	100	9,666	11,200	140	11,340
Germany	3,077	6,800	9,877	3,100	7,700	10,800
Bahrein Island	4,645		4,645	7,400		7,400
British Borneo	4,818	100	4,918	6,130	130	6,260
Poland	3,870	500	4,370	3,700	500	420
Canada	140	1,364	1,504	1,100	1,800	2,900
Japan	2,403	150	2,553	2,500	150	2,650
Ecuador	1,943		1,943	2,200		2,200
Egypt	1,242	50	1,292	1,200	50	1,250
Others	1,016	5,200	6,216	1,000	5,400	6,400
	1,796,861	68,136	1,864,997	2,034,030	75,790	2,109,820

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* See page 308, this volume.

TABLE 3.—*World Consumption of Petroleum Products and Related Fuels*[a]

THOUSANDS OF BARRELS

Country	1936						1937					
	Motor Fuel	Kerosene	Gas and Fuel Oil	Lubricants	Miscellaneous	Total	Motor Fuel	Kerosene	Gas and Fuel Oil	Lubricants	Miscellaneous	Total
United States	481,530	51,430	410,440	22,320	127,030	1,092,750	517,000	55,000	442,000	23,900	130,000	1,167,900
Russia	22,220	39,150	59,580	8,500	18,000	147,450	24,000	41,000	64,000	9,200	20,000	158,200
United Kingdom	40,250	6,530	25,810	3,410	3,970	79,970	43,000	6,600	27,400	3,700	4,300	85,000
France	24,400	1,820	15,970	2,130	4,470	48,790	25,000	1,700	17,200	2,300	4,700	50,900
Canada	20,630	780	11,890	3,300	3,800	40,400	21,000	600	14,000	3,600	4,300	43,500
Germany	17,710	2,220	15,650	1,260	2,080	38,920	20,000	2,250	17,000	1,300	2,450	43,000
Japan	10,000	1,840	17,000	2,150	2,600	33,590	10,400	2,000	16,500	2,500	2,700	34,100
Argentina	6,180	1,230	15,490	330	1,470	24,700	6,300	1,200	16,000	300	1,500	25,300
Mexico	2,900	950	12,700	250	1,450	18,250	3,600	1,000	15,000	300	1,690	21,590
Italy	4,210	1,480	9,480	630	1,100	16,900	5,200	900	11,300	900	1,700	20,000
Netherlands West Indies	180	30	12,500	40	3,900	16,650	180	30	13,500	40	4,300	18,050
British India	2,480	6,500	3,800	990	1,300	15,070	2,650	6,950	4,100	1,050	1,400	16,150
Australia	7,300	1,170	3,470	430	900	13,270	7,500	1,300	3,600	450	1,000	13,850
Rumania	810	1,290	10,500	220	2,000	14,820	700	1,000	9,000	200	1,500	12,400
Netherlands Indies	1,500	2,000	5,100	200	1,300	10,100	1,500	1,950	6,100	250	1,500	11,300
Netherlands	3,480	1,700	2,800	360	700	9,040	3,500	2,000	3,500	400	1,000	10,400
Iran	500	1,000	4,600	300	2,000	8,400	540	1,080	4,900	320	2,100	8,940
Sweden	3,740	840	2,500	360	490	7,930	4,000	900	2,900	400	700	8,900
Venezuela	590	30	1,200	40	5,900	7,760	650	30	1,300	40	6,300	8,320
Brazil	2,750	790	4,190	220	100	8,050	2,700	850	4,200	250	100	8,100
Belgium	4,300	350	1,200	400	500	6,750	4,600	370	1,300	430	530	7,230
China	990	2,460	2,800	260	340	6,850	1,000	2,500	2,900	280	360	7,040
Union of So. Africa	3,560	400	1,670	240	300	6,170	3,800	430	1,790	260	320	6,600
Denmark	2,500	700	1,800	350	200	5,550	2,700	700	2,100	350	200	6,050
Egypt	700	1,700	2,300	140	400	5,240	750	1,820	2,460	150	430	5,610
Spain	2,800	190	1,650	100	210	4,950	2,900	200	1,700	100	200	5,100
Norway	1,200	280	2,000	100	140	3,720	1,600	500	2,500	150	200	4,950
New Zealand	2,800	200	1,200	100	200	4,500	3,000	210	1,280	110	210	4,810
Cuba	490	70	3,750	40	110	4,460	520	70	4,000	40	120	4,750
Trinidad	110	70	3,800	30	290	4,300	120	70	4,100	30	310	4,530
Philippine Islands	1,000	580	2,400	80	130	4,190	1,080	620	2,570	90	140	4,500
British Malay	690	330	2,400	70	200	3,690	1,000	330	2,800	120	200	4,450
Iraq	350	220	2,100	60	750	3,480	370	230	2,300	60	800	3,760
Chile	570	60	2,550	70	40	3,290	610	60	2,730	70	40	3,510
Hawaiian Islands	980	140	1,990	70	70	3,250	1,050	150	2,130	70	70	3,470
Switzerland	1,650	170	1,200	120	50	3,190	1,700	200	1,300	150	100	3,450
Czechoslovakia	1,700	590	520	250	50	3,110	1,820	630	560	270	50	3,330
Austria	910	280	1,200	150	150	2,690	970	300	1,280	160	160	2,870
Poland	550	960	420	300	500	2,730	600	1,000	450	300	450	2,800
Peru	550	200	1,500	30	300	2,580	590	210	1,600	30	320	2,750
Uruguay	630	60	1,800	40	40	2,570	670	60	1,920	40	40	2,730
Panama Canal Zone	110	30	2,300	20	40	2,500	120	30	2,460	20	40	2,670
Greece	510	200	1,400	70	60	2,240	600	170	1,400	60	70	2,300
Irish Free State	1,100	510	270	70	200	2,150	1,200	520	270	70	200	2,260
Algeria	970	350	370	70	160	1,920	1,050	380	400	70	170	2,070
Hungary	550	450	600	100	100	1,800	590	480	640	110	110	1,930
Puerto Rico	490	70	990	30	40	1,620	520	70	1,060	30	40	1,720
Finland	750	550	100	100	100	1,600	800	590	110	110	110	1,720
Portugal	570	390	270	60	70	1,360	610	420	290	60	70	1,450
French Morocco	770	90	110	40	130	1,140	820	100	110	40	140	1,210
Others	6,700	5,550	23,200	1,040	2,670	39,160	7,200	6,000	24,800	1,120	2,900	42,020
Totals	694,910	140,980	714,530	52,040	193,100	1,795,560	744,380	147,760	768,810	56,350	202,240	1,919,540

[a] Consumption figures include crude consumed as such, all its products and related fuels such as benzol, natural gasoline, alcohol used as motor fuel. Oil delivered to ships bunkers is included in consumption of country where deliveries are made.

DISCUSSION

(*M. Albertson presiding*)

J. B. UMPLEBY,* Seattle, Wash.—What word did you use in describing present conditions in petroleum production?

V. R. GARFIAS.—The expression was "OIPO," meaning "oversupply of immediately producible oil." Let me explain further: The present condition of petroleum production may be compared to that of a man in deep water. As long as the water level is below his nose he is safe but ½ in. of water above will very likely drown him. Formerly the producer always had that gambling chance, the ever-present prospect of a bonanza, the gusher, which even in times of overproduction and low prices meant a fortune. This created the "flood and famine" era of the industry, the days of wide fluctuations in price, of fortunes overnight. With restricted production, proration and allowables, came the stability in prices, the damned-up available production, the gusher artificially turned into stripper and the impossibility of bonanzas. For several years, the business of oil production has struggled with an Oversupply of Immediately Producible Oil (abbreviated to OIPO) which has not been great in proportion to ultimate reserves or to the demand, forming a thin layer of unnecessary but immediately available oil, which demoralizes the entire industry.

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* Petroleum Engineer.

C. A. WARNER,* Houston, Texas.—Have you considered the reserves that might be producible in the future owing to improved production methods or higher price of oil?

V. R. GARFIAS.—Figures of reserves as published have little meaning. No effort is made to differentiate between economic and uneconomic reserves, nor is the time element taken into account. Some of the so-called reserves are not assets; they are liabilities. In estimating proven reserves, only oil that can be economically produced at a given time should be considered.

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* Houston Oil Company of Texas.

World Consumption of Petroleum Products and Related Fuels for Military Purposes

By V. R. Garfias* and R. V. Whetsel,* Members A.I.M.E., and J. W. Ristori*

(New York Meeting, February, 1938)

During the past eight years, in trying to estimate world consumption of petroleum and related products, the authors have been unable to account for all the supplies available in any one year. There has remained at all times a balance, which at first was thought to represent almost entirely additions to stocks in foreign countries. But as this discrepancy continued year after year—over 148,000,000 bbl. in 1937—it became unreasonable to conclude that corresponding additional foreign storage capacity was continuously being made available. It became therefore clear that the balance in question was due to other causes than to additions to stocks.

Last year Mr. A. G. White, Chief Economist of the Petroleum Economics Division of the United States Bureau of Mines, pointed out to one of the authors that an unknown and important factor in consumption of petroleum and related products is to be found in the requirements for military purposes in foreign countries. This paper is the result of Mr. White's timely suggestion. There are no reliable data available either on the storage capacity, and therefore oil stocks, or on the petroleum consumption for military purposes in foreign countries. This information is so closely related to national defense that its divulgation is forbidden. One can therefore but surmise as to these facilities and needs in line with the relative strength of the military land, air and sea forces of the various countries.

The authors have assumed many of the component factors that go to make the tables herein presented, such as fuel consumption of fighting ships in relation to tonnage and horsepower, gasoline consumption of air fleets in relation to number of planes, and the consumption of petroleum products by mechanized armies; but in making these assumptions they have availed themselves of the advice and counsel of those whose wide experience in these questions make their views authoritative.

The opportunities for error in an estimate of this nature are obvious and ever present; to illustrate: The air fleets in Spain no doubt consumed

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* Cities Service Co., New York, N. Y.

more gasoline in 1937 than the same number of military planes in France, while the Japanese Navy, as a result of the hostilities in China, obviously needed during the year more fuel oil than, say, a corresponding American fleet. Also, the German Army, more thoroughly mechanized, utilized in 1937 more petroleum products than the warring armies of China, which "on paper" greatly outnumber the former. The authors have made what they believe to be adequate allowances for these and other similar conditions and therefore feel that their conclusions do represent a fair approximation to the actual facts.

TABLE 1.—*World Consumption of Petroleum and Related Products by Armies in 1937*[a]

U. S. BARRELS

Country	Personnel	Gas and Fuel Oil	Motor Fuel	Lubricants	Total
Argentina	37,000		10,700	300	11,000
Austria	38,000		10,700	300	11,000
Belgium	92,000		21,500	600	22,100
Brazil	66,000		12,900	300	13,200
British Empire	385,000		300,000	9,000	309,000
Bulgaria	44,000		5,400	200	5,600
China	1,750,000		5,400	200	5,600
Czechoslovakia	164,000		26,900	800	27,700
Finland	30,000		5,400	200	5,600
France	659,000		269,000	7,500	276,500
Germany	650,000		150,000	4,000	154,000
Greece	80,000		15,000	400	15,400
Hungary	44,000		10,700	300	11,000
Italy	1,332,000		306,000	9,200	315,200
Japan	600,000		242,000	6,800	248,800
Mexico	57,000		10,700	300	11,000
Poland	333,000		107,000	3,000	110,000
Portugal	61,000		17,200	500	17,700
Rumania	222,000		64,500	1,800	66,300
Russia	1,545,000		322,000	9,500	331,500
Spain	500,000		242,000	6,800	248,800
Sweden	34,000		10,900	300	11,000
Turkey	133,000		26,900	800	27,700
Yugoslavia	132,000		26,900	800	27,700
United States	170,000	960,000	242,000	6,800	1,208,800
Others	220,000	2,240,000[b]	215,000	6,000	2,461,000
	9,378,000	3,200,000	2,676,500	76,700	5,953,200

[a] In addition, some 10,000 bbl. of miscellaneous products were consumed by armies in 1937.

[b] Represents gas and fuel oil consumed by the armies of countries shown in this table and on which no segregation by countries was attempted.

With the foregoing and similar limitations in mind, the authors present this paper, having as its main purpose to account in part for the "unaccounted-for balance" appearing in previous estimates of world consumption.

It should be noted that it has been and will be impracticable to fully account in any one year for the available world supply of petroleum and related products, until accurate information is available regarding oil stocks and consumption for military purposes in foreign countries.

TABLE 2.—*World Consumption of Petroleum and Related Products by Navies in* 1937[a]

U. S. BARRELS

Country	Tonnage	Horsepower	Gas and Fuel Oil	Lubricants	Total
Argentina	100,000	350,000	742,000	2,000	744,000
Brazil	59,000	118,000	439,000	1,200	440,200
British Empire	1,256,000	6,450,000	10,526,000	28,800	10,554,800
Chile	75,000	150,000	500,000	1,300	501,300
China	52,000	105,000	400,000	1,000	401,000
Cuba	15,000	30,000	116,000	300	116,300
Denmark	16,000	34,000	120,000	300	120,300
Finland	15,000	37,000	116,000	300	116,300
France	516,000	2,730,000	4,600,000	13,500	4,613,500
Germany	135,000	695,000	1,000,000	2,600	1,002,600
Greece	37,000	74,000	275,000	700	275,700
Italy	425,000	3,620,000	3,465,000	9,800	3,474,800
Japan	813,000	4,524,000	6,200,000	18,000	6,218,000
Netherlands[b]	88,000	616,000	660,000	1,900	661,900
Norway	40,000	60,000	300,000	900	300,900
Portugal	26,000	55,000	200,000	600	200,600
Russia	193,000	483,000	1,498,000	4,500	1,502,500
Spain	100,000	546,000	742,000	2,200	744,200
Sweden	85,000	255,000	630,000	1,700	631,700
Turkey	44,000	88,000	320,000	900	320,900
United States	1,146,000	5,996,000	8,250,000	24,000	8,274,000
Others	150,000	300,000	1,000,000	2,000	1,002,000
	5,386,000	27,316,000	42,099,000	118,500	42,217,500

[a] In addition, about 20,000 bbl. of miscellaneous products were consumed by navies in 1937.

[b] Includes Netherlands Indies.

Tables 1, 2 and 3 show the relative strength in 1937 of the armies, navies and military air forces, respectively, and the estimates of consumption of petroleum and related products in the various countries. Table 4, which summarizes the other tables, shows that in 1937 close to 60,000,000 bbl. was consumed for military purposes. This total is some 8,000,000 bbl. higher than corresponding figures for 1936, indicating, as was to be expected, that the increase in consumption for military purposes has kept pace with the added world demand of these products for nonmilitary activities.

TABLE 3.—*World Consumption of Petroleum and Related Products by Military Air Forces in 1937*[a]
U. S. BARRELS

Country	Personnel	Planes	Motor Fuel	Lubricants	Total
Argentina	1,750	175	48,000	1,600	49,600
Belgium	2,370	225	62,000	2,100	64,100
Brazil	4,000	75	20,000	700	20,700
British Empire	57,040	4,800	1,337,000	44,000	1,381,000
Chile	2,040	225	62,000	2,100	64,100
China	2,500	250	70,000	2,300	72,300
Denmark	1,100	90	25,000	800	25,800
France	54,000	4,700	1,309,000	43,000	1,352,000
Germany	50,000	4,500	1,253,000	41,000	1,294,000
Greece	6,750	150	42,000	1,400	43,400
Italy	50,000	4,500	1,253,000	41,000	1,294,000
Japan	40,000	3,000	835,000	27,000	862,000
Poland	8,000	400	112,000	3,600	115,600
Rumania	15,000	1,000	281,000	9,000	290,000
Russia	150,000	4,500	1,253,000	41,000	1,294,000
Spain	5,200	500	240,000	8,600	248,600
Sweden	4,700	300	105,000	2,700	107,700
Turkey	10,000	400	112,000	3,600	115,600
United States	35,000	3,400	946,000	31,000	977,000
Others	3,500	350	100,000	3,400	103,400
	502,950	33,540	9,465,000	309,900	9,774,900

[a] In addition, about 40,000 bbl. of miscellaneous products were consumed by military air forces in 1937.

TABLE 4.—*World Consumption of Petroleum and Related Products for Military Purposes in 1937*[a]

U. S. BARRELS

Countries	Motor Fuel	Gas and Fuel Oil	Lubricants	Total
Argentina	58,700	742,000	3,900	804,600
Austria	10,700		300	11,000
Belgium	83,500		2,700	86,200
Brazil	32,900	439,000	2,200	474,100
British Empire	1,637,000	10,526,000	81,800	12,244,800
Bulgaria	5,400		200	5,600
Chile	62,000	500,000	3,400	565,400
China	75,400	400,000	3,500	478,900
Cuba		116,000	300	116,300
Czechoslovakia	26,900		800	27,700
Denmark	25,000	120,000	1,100	146,100
Finland	5,400	116,000	500	121,900
France	1,578,000	4,600,000	64,000	6,242,000
Germany	1,403,000	1,000,000	47,600	2,450,600
Greece	57,000	275,000	2,500	334,500
Hungary	10,700		300	11,000
Italy	1,559,000	3,465,000	60,000	5,084,000
Japan	1,077,000	6,200,000	51,800	7,328,000
Mexico	10,700		300	11,000
Netherlands[b]		660,000	1,900	661,900
Norway		300,000	900	300,900
Poland	219,000		6,600	225,600
Portugal	17,200	200,000	1,100	218,300
Rumania	345,500		10,800	356,300
Russia	1,575,000	1,498,000	55,000	3,128,000
Spain	482,000	742,000	17,600	1,241,600
Sweden	115,700	630,000	4,700	750,400
Turkey	138,900	320,000	5,300	464,200
United States	1,188,000	9,210,000	61,800	10,459,800
Yugoslavia	26,900		800	27,700
Others	315,000	3,240,000[c]	11,400	3,566,400
	12,141,500	45,299,000	505,100	57,945,600

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[a] In addition, about 70,000 bbl. of miscellaneous products were consumed for military purposes during 1937.

[b] Includes Netherlands Indies.

[c] Includes 2,240,000 bbl. of fuel oil consumed by the armies of countries shown in this table and on which no segregation by countries was attempted.

Chapter V. Production

Introduction

By James Terry Duce,[*] Member A.I.M.E.

In order to facilitate interpretation of the data in this chapter, we print the following excerpts from circulars to authors, compiled by Mr. Frank A. Herald when he was Vice-chairman for Production of the Petroleum Division:

> Generally in Table 1 the unit for presentation of data is a field. For our purposes a field is defined as the whole of a surface area wherein productive locations are continuous. Such unit commonly includes and surrounds nonproductive areas. Such unit commonly includes a great variety of geologic conditions—several units of continuous productive reservoirs of distinctly different structure and of distinctly different stratigraphy. Therefore it is hoped that our authors will subdivide "field" so as to enable students to make analyses that may have scientific and/or commercial value.
>
> As to each space in the tabulation, it is either (1) not applicable, (2) the proper entry is not determinable, (3) the proper entry is determinable, but not determinable from data available to the author, (4) the proper entry is determinable by the author. In spaces not applicable, the author will please draw horizontal lines; in spaces where the proper entries are not determinable, the author will please insert *x*; in spaces where the proper entries are determinable but not determinable from data available to the author, the author will please insert *y*; in spaces where the proper entries are determinable by the author he will, of course, make such entries. Generally, *y* implies a hope that in some future year a definite figure will be available.
>
> Inability to determine precisely the correct entry for a particular space should not lead the author to insert merely *y*. Contributions of great value may be made by the author in many cases where entries are not subject to precise determination. In such cases the author should use his good judgment and make the best entry possible under the circumstances. For many spaces, the correct entries represent the opinion of the author (for example, "Area Proved") and in such cases the entries need not be hedged to such extent as in cases where the quantities are definite yet can be ascertained only approximately by the author.
>
> In cases under definite headings but where figures are only approximate, the author may use *x*. For example, if the total production of a field is known to be between 1,800,000 and 1,850,000, the author may report 1,8*xx*,*xxx*; or if the production is between 1,850,000 and 1,900,000, the author may report 1,9*xx*,*xxx*.
>
> Where a numeral is immediately to the left of *x* or *y*, such numeral represents the nearest known number in that position.
>
> As to quantity of gas produced from many fields the question will arise as to whether the figures should include merely the gas marketed or should include also estimates of gas used in operations and gas wasted. Although rough approximations

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[*] Geologist, The Texas Company, New York, N. Y.; Vice-chairman for Production, A.I.M.E. Petroleum Division, 1936–1937 and 1937–1938.

may be involved, our figures should represent as nearly as possible the total quantity of gas removed from the reservoir.

While we have not provided a column for showing the thickness of the productive zone, generally the difference between average depth to bottoms of productive wells and average depth to top of productive zone will represent approximately the average thickness of the productive zone. For fields where this is not true because of unusually high dips, or for other reasons, it is suggested that the authors indicate in their texts the approximate average thickness of the productive zone.

The figure representing net thickness of producing rock should correspond to the total of the net portions of the producing zone which actually yield oil into the drill hole. It is recognized that for some fields the authors can make only rough guesses—so rough that figures would be of no value. In such cases the authors should enter either x or y, whichever is more appropriate.

We are particularly anxious to have every author give due consideration to the determination of structural conditions of each oil and/or gas body. Please consider each oil and/or gas reservoir and indicate its structure. The mere fact that a reservoir is on an anticline is not proof that the structural condition affecting the accumulation is anticlinal; for example, an oil and/or gas body limited by the upper margin of a lens on the limb of an anticline is "ML" as to structure. By all means, if the oil body occupies any position in the lens other than its upper limit, please so indicate clearly by footnote, for "ML" means, unless modified, that the accumulation is at the upper part of the lens. In every case where the oil and/or gas body terminates short of the up-dip continuity of the reservoir, please carefully check your evidence and then appropriately record your conclusion. "Terrace," "Nose" and "Syncline" are the only terms in our legend which presume such continuity.

Please note that the heading "Number of Dry and/or Near-dry Holes" is intended to cover only such holes as are within the limits of the defined fields.

In Table 2 are listed the important wildcat wells completed during the year. By the term "important" is meant: wells discovering new fields; wells resulting in the discovery of important extensions to old fields; wells discovering new zones in old fields; wells condemning important areas or resulting in significant stratigraphic information, even if the wells are dry; and exceptionally deep wells. At the foot of this table the total number of wells drilled in each district is given, segregated as to oil wells, gas wells and dry holes. The number of wells drilling on Dec. 31, 1937 are in two divisions, designated as wildcat wells and wells in proven fields.

FOOTNOTES TO COLUMN HEADINGS—TABLE 1

[a] In areas where both oil and gas are produced, unless gas is marketed outside the field, such areas are included in column headed "Oil." Manufacture of casinghead gasoline and carbon black is interpreted as outside marketing of gas.

[b] Wells producing both oil and gas are classified as "Producing Oil Only" unless gas from them is marketed off the lease.

[c] W, water; G, gas; A, air; AG, air-gas mixture. Numbers following letters indicate numbers of injection wells.

[d] Bottom-hole pressures are preceded by "e." All other figures represent pressures at casinghead with well closed.

[e] P, paraffin; A, asphalt; M, mixed.

[f] Cam, Cambrian; Ord, Ordovician; Sil, Silurian; Dev, Devonian; Mis, Mississippian; MisL, Lower Mississippian; MisU, Upper Mississippian; Pen, Pennsylvanian; Per, Permian; Tri, Triassic; Jur, Jurassic; CreL, Lower Cretaceous; CreU, Upper Cretaceous; Eoc, Eocene; Olig, Oligocene; Mio, Miocene; Pli, Pliocene.

[g] S, sandstone; SH, sandstone, shaly; Ss, soft sand; H, shale; L, limestone; LS, limestone, sandy; C, chalk; A, anhydrite; D, dolomite; Da, arkosic dolomite; GW, granite wash; P, serpentine; O, oolite; Slt, siltstone.

[h] Figures are entered only for fields where the reservoir rock is of pore type. Figures represent ratio of pore space to total volume of net reservoir rock expressed in per cent. "Por" indicates that the

reservoir rock is of pore type but said ratio is not known by the author. "Cav" indicates that the reservoir rock is of cavernous type; "Fis," fissure type.

[i] A, anticline; AF, anticline with faulting as important feature; Af, anticline with faulting as minor feature; AM, accumulation due to both anticlinal and monoclinal structure; H, strata are horizontal or near horizontal; MF, monocline-fault; MU, monocline-unconformity; ML, monocline-lens; MC, monocline with accumulation due to change in character of stratum; MI, monocline with accumulation against igneous barrier; MUP, monocline with accumulation due to sealing at outcrop by asphalt; D, dome; Ds, salt dome; T, terrace; TF, terrace with faulting as important feature; N, nose; S, syncline.

[j] Information will be found in text as indicated by symbols; A, name of author, other than above, who has compiled the data on the particular field; C, chemical treatment of wells; G, gas-oil ratios; P, proration; U, unit operation; R, references; W, water; O, other information.

Oil and Gas Development in South Arkansas in 1937

By H. K. Shearer,* Member, and W. B. Weeks,† Associate Member A.I.M.E.

(New York Meeting, February, 1938)

The year 1937 brought to south Arkansas increased drilling activity and production. Oil production amounted to 12,159,440 bbl., an increase of 1,504,500 bbl., or 14.1 per cent over 1936. This was the largest production since 1931, and the first annual increase since 1925, when the deeper sands at Smackover were developed.

There were 177 wells completed during the year, with 103 oil wells, 6 gas wells, and 68 dry holes, an increase of more than 100 per cent over 1936. Of the 56 wildcat wells drilled, 52 were dry and 4 produced oil. Two new fields, one important extension and three minor extensions were discovered. The trend toward deeper drilling is shown by the fact that 97 wells were more than 5000 ft. deep, including 80 over 6000 ft. and 13 over 7000 ft., although the depth record of 7973 ft., made in 1935, was not exceeded.

Geological Section

Deeper and more extensive drilling during the past few years, not only in south Arkansas but also in adjacent parts of north Louisiana and east Texas, has furnished much important geological information and has brought out some very unexpected facts in regard to structural and depositional conditions in the series of formations laid down in the interval between the end of the Pennsylvanian and early Cretaceous time. It is now evident that an important basin of salt deposition existed in the Arkansas-Louisiana-Texas area, but it is still an open question whether this salt basin was contemporaneous and continuous with the even larger Gulf Coast salt basin extending from Mississippi to Mexico.

The accompanying columnar section (Fig. 1) shows the producing zones and names that have been applied to the several subsurface formations, most of which have no outcrop equivalents. This is for the convenience of readers unfamiliar with recent developments, but the correlations and nomenclature cannot yet be considered final. These formations will be discussed in more detail in various papers to be published in the near future.

Summary presented at the meeting; manuscript received at the office of the Institute April 8, 1938.

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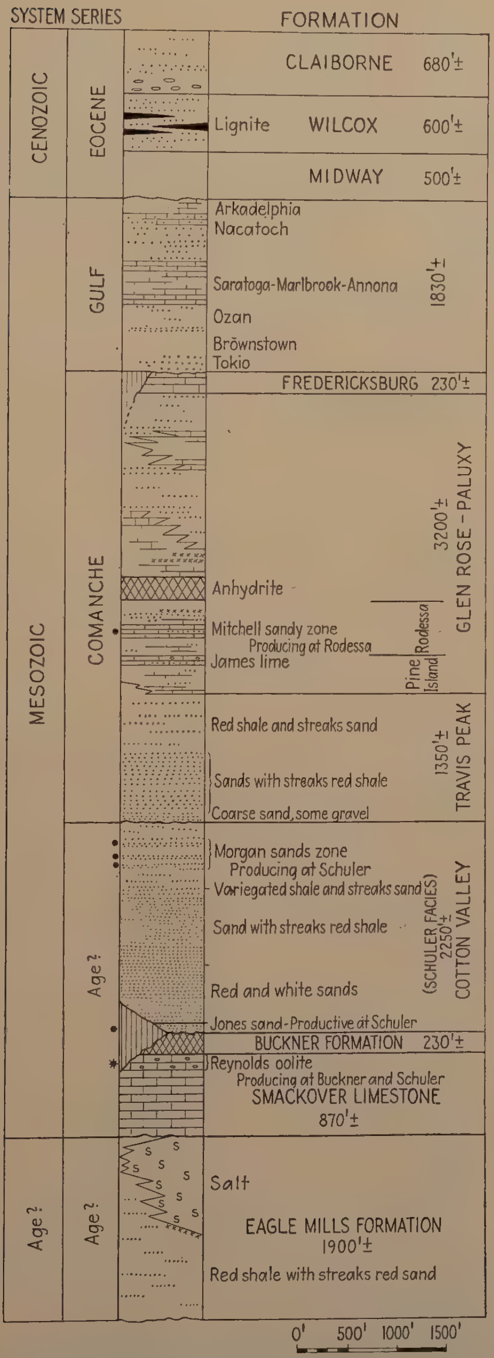

FIG. 1.—SUBSURFACE STRATA IN SOUTH ARKANSAS, SHOWING RELATIVE POSITIONS OF PRODUCING HORIZONS IN NEW FIELDS IN 1937.

The Eagle Mills formation, named from wells drilled near the village of Eagle Mills, Calhoun County, consists chiefly of red shale and sand, overlying Pennsylvanian and Mississippian formations, underlying and evidently in part contemporaneous with the mass of rock salt. The age of the salt and associated red beds is still unknown, but they seem to be more closely associated with overlying than with underlying formations.

The thick limestone bed above the salt is now called the Smackover limestone, with the Reynolds oolitic zone at the top. The age is believed to be early Mesozoic, possibly Jurassic, as the few fossils found are reported not to be Paleozoic in type.

TABLE 1.—*Oil and Gas Production in South Arkansas in* 1937

Line Number	Field, *County*	Age, Years to End of 1937	Area Proved, Acres				Total Oil Production, Bbl.	
			Oil	Oil and Gas[a]	Gas[4]	Total	To End of 1937	During 1936
1	Bradley, *Lafayette*	13	80	0	0	80	186,705	0
2	Buckner, *Columbia*	1/12	40[3]	0	0	40	21,490	0
3	Camden, *Ouachita*	3	10	0	0	10	35,920	8,025
4	Champagnolle, *Union*	11	2,000	x	x	2,000	13,159,320	979,525
5	East El Dorado,[1] *Union*	16	1,420	x	x	1,420	8,976,265	188,830
6	El Dorado, *Union*	18	8,000	x	x	8,000	46,476,980	582,835
7	Garland City,[2] *Miller*	6	300	0	0	300	1,606,015	325,045
8	Irma, *Nevada*	17	900	x	x	900	6,206,425	307,770
9	Lisbon, *Union*	12	2,700	x	x	2,700	6,439,465	105,985
10	Mount Holly, *Ouachita*	9	60	0	0	60	117,085	0
11	Rodessa, *Miller*	½	2,000[3]	x	x	2,000	1,235,045	0
12	Schuler, *Union*	¾	1,000[3]	x	x	1,000	1,208,420	0
13	Smackover, *Ouachita, Union*	16	25,600	160	x	25,760	365,701,920	7,252,095
14	Heavy oil area	16	16,000	x	x	16,000	313,067,650	6,404,000
15	Light oil area	16	9,600	x	x	9,600	52,538,470	794,095
16	Snow Hill area	2	0	160	0	160	95,900	54,000
17	Stephens, *Columbia, Nevada, Ouachita*	16	3,000	x	x	3,000	5,961,400	214,005
18	Troy, *Nevada*	2	250	40	x	290	285,560	15,770
19	Urbana, *Union*	8	500	x	x	500	4,105,730	675,055
20	Total		47,860	x	x	48,060	461,723,745	10,654,940

[a] Footnotes to column heads and explanation of symbols are given on page 313.

[1] Including other small producing areas.

[2] Includes the one Glen Rose producer in sec. 24, T. 15 S., R. 26 W.

[3] Areas of the Buckner and Schuler fields are still undefined. Rodessa is partly defined, and no large extensions are expected there.

[4] Champagnolle, East El Dorado, El Dorado, Irma, Lisbon and Smackover produced large quantities of gas in earlier years, some of which was used commercially. Stephens produced some gas from the Nacatoch and Urbana from the 2700-ft. sand.

Beds above the limestone, characterized by anhydrite but containing also shale and dolomitic limestone, are called the Buckner formation, from the Buckner oil field.

The formation underlying the basal gravel of the Travis Peak and overlying the Buckner formation or older beds (where the Buckner is absent) is locally termed the Schuler formation, or Schuler facies of the Cotton Valley formation. It includes the Morgan sands zone, near the top, and the Jones sand, at its base, in the Schuler pool in Union County. This formation apparently corresponds in age and stratigraphic position with the marine beds named the Cotton Valley formation in Louisiana, but is lithologically distinct, since it consists dominantly of varicolored shale, sand and siltstone of nonmarine type. The age remains undetermined, except that it is evidently older than any of the Comanche Cretaceous as known in surface exposures in Arkansas and Texas.

TABLE 1.—(*Continued*)

Line Number	Total Oil Production, Bbl.		Total Gas Production, Millions Cu. Ft.		Number of Oil and/or Gas Wells								Depth, Average in Feet		Oil Production Methods at End of 1937			Pressure, Lb. per Sq. In.^{d}	
						During 1937		At End of 1937							Number of Wells				Average at End of
	During 1937	Daily Average during Dec. 1937	To End of 1937^4	During 1937	Completed to End of 1937	Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Oil and Gas^b	Producing Gas Only	Total Producing	Bottoms of Productive Wells	To Top of Productive Zone	Flowing	Pumping	Gas-lift	Initial	1937
1	0	0	0	0	6	0	0	0	0	0	0	0	2,790	2,785	0	0	0	*y*	0
2	21,490	693	0	0	1	1	0	0	1	0	0	1	7,258	7,195	1	0	0	e3,200	e3,200
3	3,395	10	0	0	1	0	0	0	1	0	0	1	1,369	1,356	0	1	0	*y*	*y*
4	548,590	1,285	*x*	*x*	225	0	0	5	79	0	5	84	2,800 to 3,350	2,780 to 3,340	0	79	0	*y*	*y*
5	159,690	415	*x*	0	187	0	2	7	59	0	0	59	2,180	2,170	0	59	0	*y*	*y*
6	564,945	1,470	*x*	0	1,115	3	3	10	224	0	0	224	2,177	2,100 2,550 2,950	0	224	0	*y*	*y*
7	175,690	355	0	0	28	1	1	2	21	0	0	21	2,935 4,215	2,925 4,200	0	21	0	*y*	*y*
8	274,255	720	*x*	0	148	6	3	18	63	0	0	63	1,179	1,150	0	63	0	*y*	*y*
9	99,815	280	*x*	0	356	0	0	9	141	0	0	141	2,120	2,100	0	141	0	*y*	*y*
10	0	0	0	0	6	0	0	0	0	0	0	0	2,813	2,800	0	0	0	*y*	0
11	1,235,045	9,645	*x*	*x*	59	59	0	0	55	4	0	59	6,100	6,050	59	0	0	*y*	*y*
12	1,208,420	10,250	800^5	800	22	22	0	0	21	1	0	22	5,884 7,610 7,635	5,600 7,528 7,600	19	2	1	e3,450 e3,544	e3,450 e3,544
13	6,913,380	18,430	*x*	*x*	3,732	1	27	128	1,740	0	11	1,751			0	1,740	0		
14	6,101,935	16,305	*x*	*x*	*y*	0	19	94	1,205	0	11	1,216	2,025 2,475 2,610	2,000 2,450 2,600	0	1,205	0	*y*	*y*
15	769,545	2,025	*x*	*x*	*y*	0	6	32	533	0	0	533	2,025 2,300	2,000 2,275	0	533	0	*y*	*y*
16	41,900	100	*y*^{6}	*y*	6	1	2	2	2	0	0	2	4,960	4,800	0	2	0	*y*	*y*
17	209,515	560	*x*	0	304	1	0	10	189	0	0	189	1,510 2,110	1,500 2,100	0	189	0	*y*	*y*
18	269,790	1,145	*y*	*y*	16	11	0	3	11	0	2	13	1,250 2,167	1,243 2,160	0	11	0	*y*	*y*
19	475,420	1,200	*x*	0	45	4	0	4	32	0	0	32	2,280 3,560	2,270 3,550	0	32	0	*y*	
20	12,159,440	46,458	*x*	*x*	6,251	109	36	196	2,637	5	18	2,660			79	2,562	1		

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[5] Gas from the one Smackover lime well at Schuler is piped to El Dorado for use in the Lion Oil Refining Company's refinery, in addition to use for drilling operations.

[6] Gas from Snow Hill wells was used for pumping operations in the Smackover field, but is already nearly exhausted.

For the upper part of the "lower Trinity red beds" the name "Travis Peak" is retained because of common usage, although the correlation with the type Travis Peak of Texas is very doubtful.

The Glen Rose formation (or subgroup) of the Trinity group is best known and most productive in Louisiana, and is a definable unit, but possibly includes more than the age equivalent of the type Glen Rose. At the top are the Paluxy red beds, grading southward and downward into marine limestones, and in the middle is the well-known anhydrite member. Below the anhydrite and down to the James limestone is what may be called the Rodessa member, with various producing lenses or tongues. Below the James limestone is a bed of black shale, which thickens southward and is in turn underlain by beds of oolitic limestone, which produce oil in the Pine Island, Sligo and Lisbon pools and gas at various other localities. Both shale and limestone are included in the Pine Island

TABLE 1.—(*Continued*)

	Character of Oil, Approx. Average during 1937					Producing Rock							Deepest Zone Tested to End of 1937	
	Gravity A.P.I. at 60° F.													
Line Number	Maximum	Minimum	Weighted Average	Sulphur, Per Cent	Base[e]	Name	Age[f]	Character[g]	Porosity[h]	Net Thickness, Average in Feet	Structure[i]	Number of Dry and/or Near-dry Holes to End of 1937	Name	Depth of Hole, Ft.
1	28	25	27	*y*	M	Buckrange	CreU	S	Por	5	T?	5	Paluxy	3,555
2			32	*y*	P	Smackover ls.	L. Mes.?	O	10–20	85	Af?	0	Smackover ls.	7,309
3			17	*y*	A	Nacatoch	CreU	S	Por	13		5	Travis Peak	2,500
4	38	18	36	1.1	M	Tokio Travis Peak	CreU CreL	S	Por	15	NL	137	Rock salt	6,911
5	21	17	20	1.8	A	Nacatoch	CreU	S	Por	10	TL	41	Schuler	6,003
6	39	30	32	1.0	M	Nacatoch	CreU	S	Por	20	ANL	157	Travis Peak	3,396
7	33	27	30	1.2	M	Paluxy Rodessa member	CreL	S	Por	10	ML	36	Smackover ls.	7,310
8	16	14	14	2.7	A	Nacatoch	CreU	S	Por	15	AF	27	Travis Peak	3,735
9	38	28	35	1.0	M	Nacatoch	CreU	S	Por	20	ML	18	Travis Peak	3,509
10	32	28	30	*y*	M	Travis Peak	CreL	S	Por	7	ML	14	Travis Peak	3,378
11	65	42	43 65	0.1	P	Rodessa member	CreL	S, L, LS, O	Por	5 to 25	AF	1	L. Glen Rose	6,514
12	66	32	41 32	1.3	P	Schuler	L. Mes.?	S	14.5	20 60				
13			64	0.08		Smackover ls.		O	10.0	50	A	47[7] 364	Smackover ls.	7,950
14	25	17	21	2.2	A	Nacatoch, Graves, Tokio	CreU	S	Por	40	AS	*x*	Rock salt	7,255
15	32	25	25	1.8	M	Nacatoch, Meakin	CreU	S	Por	30	TLf	*x*	Paleozoic Igneous	7,973
16	52	50	50	*y*	P	Smackover ls.	L. Mes.?	O	Por	30	AF	3	Rock salt	5,708
17	33	13	28	2.9 1.6	A M	Nacatoch Buckrange	CreU	S	Por	15 7	NLF	47	Schuler	4,502
18	21	14	14 21	*y*	A	Nacatoch, Tokio	CreU	S	Por	10	F	3	Rock salt	6,143
19	20	16	20	2.1	A	Nacatoch Travis Peak	CreU CreL	S	Por	10	A	36	Travis Peak	4,501
20												894		

[7] Four wells dry in Morgan zone, all will probably be deepened.

member, so named because production was first obtained from the Dixie and Dillon zones on the Pine Island structure.

Wells drilled in Arkansas during 1937 penetrated various formations down to the Paleozoic. Several wells drilled in Nevada, Hempstead and Ouachita counties, north of the south Arkansas graben system, penetrated the gravel beds that heretofore were believed to mark the top of the Paleozoic. Evidence from these wells indicates that the gravel is basal Travis Peak, lying unconformably on the Schuler (Cotton Valley) formation or earlier beds.

Thirteen wells in six counties were drilled into the Smackover limestone, and one penetrated into the underlying salt. Two other deep tests were lost in the Buckner anhydrite just before testing the top of the limestone. It is expected that continued deep drilling during 1938 will furnish more important geologic information.

NEW FIELDS

Schuler.—On April 6, 1937, the Lion Oil Refining Co. and Phillips Petroleum Company's No. A-1 Morgan, sec. 18, T. 18 S., R. 17 W., in

TABLE 2.—*Summary of Drilling Operations in Arkansas*, 1937

Important Wildcats Drilled in 1937

	County	Location			Total Depth, Ft.	Surface Formation	Deepest Horizon Tested
		Sec.	Twp.	Rge.			
1	Ashley	18	17 S	9 W	5611	Claiborne	Smackover ls.
2	Calhoun	34	11 S	13 W	3505	Claiborne	Eagle Mills
3	Clark	14	10 S	20 W	2770	Wilcox	Pennsylvanian
4	Cleveland	36	10 S	11 W	3958	Jackson	Pennsylvanian
5	Cleveland	22	9 S	10 W	3819	Jackson	Pennsylvanian
6	Columbia	8	16 S	22 W	7309	Claiborne	Smackover ls.
7	Columbia	24	17 S	19 W	7561	Claiborne	Buckner
8	Hempstead	21	14 S	25 W	4510	Wilcox	Glen Rose-Rodessa member
9	Hempstead	24	14 S	24 W	4507	Wilcox	Schuler?
10	Hempstead	16	13 S	23 W	4515	Wilcox	Eagle Mills?
11	Howard	28	11 S	27 W	2936	Marlbrook	Pennsylvanian
12	Lafayette	36	19 S	26 W	6219	Claiborne	Glen Rose-Rodessa member
13	Miller	24	15 S	26 W	4215	Wilcox	Glen Rose-Rodessa member
14	Miller	24	15 S	26 W	7305	Wilcox	Smackover ls.
15	Miller	11	20 S	28 W	6103	Claiborne	Glen Rose-Rodessa member
16	Miller	11	20 S	27 W	6250	Claiborne	Glen Rose-Rodessa member
17	Nevada	9	14 S	20 W	5394	Wilcox	Smackover ls.
18	Nevada	10	14 S	20 W	6143	Wilcox	Rock salt
19	Ouachita	21	15 S	15 W	5350	Claiborne	Smackover ls.
20	Ouachita	33	13 S	18 W	4500	Claiborne	Eagle Mills?
21	Union	18	16 S	14 W	5329	Claiborne	Buckner
22	Union	18	18 S	17 W	5559	Claiborne	Schuler-Morgan zone
23	Union	Same well			7688	Claiborne	Smackover ls.
24	Union	17	18 S	17 W	7616	Claiborne	Schuler-Jones sand
25	Union	17	18 S	17 W	7950	Claiborne	Smackover ls.

western Union County was completed for 300 bbl. per day of 43° gravity oil from a depth of 5559 ft. Subsequent wells proved up a zone 250 ft. thick, containing three series of lenticular sands, altogether known as the Morgan sands zone. Fifteen producing wells were completed in this zone, of which three were drilled deeper and recompleted during the year. This zone is near the top of the Schuler formation, and is the first production from that formation in Arkansas. The field was named for the old settlement of Schuler in sec. 7, T. 18 S., R. 17 W.

E. M. Jones et al. completed the No. 1 Marine Oil Co. well on Sept. 17, through casing perforations at 7554 to 7571 ft., in a sand 60 ft. thick at the base of the Schuler formation, immediately overlying the Smackover limestone, this well having been drilled through the sand to a total depth of 7616 ft. Initial production was 2500 bbl. per day of 32° gravity oil.

TABLE 2.—(*Continued*)

Important Wildcats Drilled in 1937

	Drilled by	Initial Production per Day		Choke or Bean, Fractions of an Inch	Bottom-hole Pressure, Lb. per Sq. In.	Remarks
		Oil, U. S. Bbl.	Gas, Millions Cu. Ft.			
1	Phillips Petr. Co.					Dry
2	Hayner, Reeves & Hose					Dry
3	Coker Oil Corp.					Dry
4	J. R. Lockhart					Dry
5	Texas Canadian Dev. Co.					Dry
6	Standard Oil Co. of La.	2184		2½	3200	Plugged back to 7258. Discovery well, Buckner field
7	Tidewater-Seaboard					Dry (junked)
8	E. H. Moore, Inc.					Dry
9	Root Pet. Co.					Dry
10	Root Pet. Co.					Dry
11	Boetcher Oil Co.					Dry
12	Carl B. King					Dry
13	C. V. Lenz	50		Pumping		Discovery well, Garland City extension, and first Glen Rose producer in Arkansas
14	E. H. Moore, Inc.					Dry
15	McClanahan et al.	780		?	2400	Discovery well, Rodessa extension in Arkansas
16	F. W. Burford					Dry. Limits Rodessa field on northeast
17	Benedum & Trees					Dry
18	Benedum & Trees					Dry at 6143 ft. { Discovery well, Troy field, in 1936 Deepened, then plugged back and recompleted in original sand
19	Lion Oil Ref. Co.					Dry. Limits Snow Hill field
20	Tidewater-Seaboard					Dry
21	W. D. Wingfield et al.					Dry (junked)
22	Lion Oil Ref. Co.	1455	5	¼		Discovery well, Schuler field
23	Lion Oil Ref. Co.	600	40	½	3544	Discovery well, Smackover lime at Schuler
24	E. M. Jones et al.	2387			3450	Plugged back to 7571. Discovery well, Jones sand at Schuler
25	E. M. Jones et al.	1189				Deepest test at Schuler. Completed in Jones sand

	In Proven Fields	Wildcats
Number of wells drilling Dec. 31, 1937	23	15
Number of oil wells completed during 1937	99	4
Number of gas wells completed during 1937	6	0
Number of dry holes completed during 1937	16	52

Nine wells were completed in this Jones sand by the end of the year. The initial bottom-hole pressure was 3450 lb.

The Lion Oil Refining Co. and Phillips Petroleum Co. deepened the Morgan zone discovery well and recompleted it on Oct. 6, producing 600 bbl. of 66° gravity distillate and 40,000,000 cu. ft. of gas per day from a depth of 7688 ft., or 90 ft. in the Smackover limestone. No other wells had been completed in this Reynolds oolitic zone at the end of the year. The initial bottom-hole pressure was around 3550 lb.

Before the Jones sand discovery, four wells to the north, west and southwest of production were abandoned as dry after testing the Morgan zone, but it is probable that all of these will be deepened.

The proven producing area of the Jones sand at the end of 1937 was over 1000 acres, but only a part of the southeast flank of the structure has been explored, and the total area is sure to be much larger. Without making a premature estimate, it is safe to state that Schuler is an important oil field, and will rank second only to Smackover among Arkansas fields in ultimate production.

Buckner.—Completion of the No. 1 McKean well, Standard Oil Company of Louisiana, in sec. 8, T. 16 S., R. 22 W., Columbia County, on Nov. 30, opened the second new oil field of the year. The Smackover limestone was penetrated from 7190 to 7309 ft., but carried salt water below 7280 ft. The well was plugged back to 7258 ft. for completion, and flowed 91 bbl. per hour through 2½-in. tubing. The well did not flow steadily until after acid treatment, but the sluggishness was evidently due to low gas ratio and low permeability of the lime, rather than subnormal pressure, as bottom-hole pressure is 3200 lb. With only one well completed, nothing can be said as to structural conditions, area and oil reserve.

Extensions and Developments

Rodessa.—W. L. McClanahan et al. No. A-1 Capps Brothers, sec. 11, T. 20 S., R. 28 W., Miller County, was completed on June 13, flowing 780 bbl. per day of 42° gravity oil through ⅝-in. choke from a depth of 6103 ft., proving an extension of the Rodessa field from Louisiana into Arkansas. By the end of the year, 59 producing wells had been completed, with potentials ranging from 50 to 2400 bbl. per day. Some of the wells had high gas ratios, but only four were rated as primarily gas wells. A dry hole completed in 1936 is very close to the northwest edge of the field, and the only dry hole drilled in the area in 1937 was a wildcat several miles northeast of production.

Oil and gas production is from the Gloyd porous limestone and associated Mitchell sand lens in the lower Glen Rose, the important Dees and Young producing zones of Louisiana having dipped below salt-water level in Arkansas. Most of the wells have been completed after acid treatment.

Miller County.—The C. V. Lenz No. 7 Dale, sec. 24, T. 15 S., R. 26 W., was officially completed in January 1937, pumping 50 bbl. per day from

4215 ft., as the first Glen Rose producer in Arkansas. Three deeper offset tests in the same section were drilled in 1937. All were dry, and one of the three was drilled into the Smackover limestone at a total depth of 7310 ft. For statistical purposes the Lenz (later E. H. Moore, Inc.) well is included with the Garland City field, although it is actually a separate and deeper pool.

Troy.—The Troy field of Nevada County, discovered late in 1936, was developed and extended slowly. Eleven producers were completed, including seven Tokio sand oil wells, three Nacatoch sand oil wells, and one Nacatoch sand gas well. There were also three deep dry holes, one abandoned in the Schuler formation at 4335 ft., one in the Smackover limestone at 5394 ft., and one in rock salt at 6143 ft., the latter being the only well drilled into the salt in Arkansas during the year.

Urbana.—Two small pumping wells in the Nacatoch sand at 2180 ft., in sec. 15, T. 18 S., R. 13 W., opened a southern extension to the Urbana field in Union County. There were also two oil wells completed in the 3500-ft. Travis Peak sand in the older part of the field.

Other Fields.—There was very little drilling in old fields during the year. El Dorado, Union County, had three Nacatoch sand pumpers; Stephens, Ouachita County, had one small pumper from the Buckrange; and Irma, Nevada County, had six Nacatoch sand completions. At Snow Hill, a small gas well was completed in the Reynolds zone of the Smackover limestone, and a dry hole helped to limit the field. Production there declined rapidly, until at the end of 1937 only two oil wells were pumping, and the gas production was negligible.

Proration

Proration was not in effect in Arkansas in 1937, but an order applying to the Rodessa and Schuler fields was issued effective Jan. 1, 1938. The major companies will probably accept any reasonable regulation without protest, but the general effectiveness remains to be seen, as the Arkansas laws in regard to proration are still untested in the courts.

Prospects for 1938

With the Buckner and Schuler fields to be developed, and the expected search for other similar fields in wildcat territory, there should be a considerable increase in drilling in 1938. Operations in the Rodessa extension had declined at the end of 1937, as the producing area was practically defined, and well spacing was already too close for economy in the best part of the area.

Columbia, Lafayette and Union Counties should have the most extensive testing. Practically all wells started will have the Schuler formation and Smackover limestone as objectives, so wells more than 7000 ft. deep will be common.

Developments in the California Oil Industry during the Year 1937

By V. H. Wilhelm,* Member A.I.M.E.

(New York Meeting, February, 1938)

The trend initiated in January 1936, of stabilized gasoline prices, increased demand and extraordinary drilling activity, continued in California during the year 1937. Crude prices were maintained during the year at the highest level since September 1930. Wildcat activity with resultant new discoveries and development of proven acreage were greater than in any year since 1928. Many fields in California in former years have been produced at full capacity, with consequent loss of reservoir energy, but at the present time continued activity is maintained to develop adequate reserves, so that production in these fields can be taken at a rate to correspond with good operating practice. Naturally, this good operating practice will be influenced to some degree by gas outlets and, in certain instances perhaps, by oil outlets. In any event, these last two controlling features will result in favorable rather than detrimental operation. In fields producing from great depths, ultimate production will be practically limited to the flowing and compressor life of the well, since there is as yet no economical method for pumping wells below depths of approximately 7000 ft. Experience has shown, however, that such pumping difficulties will be overcome and that production secured by pumping will add some to reserves established on the flowing life of the wells.

California continued to operate under voluntary curtailment, but with unlimited transfers of allowable between various fields. Even though there was at all times considerable production above the Umpire's established quota, a constantly increasing demand reduced storage during the year. This increasing demand was due mainly to the rapid rise in Pacific foreign shipments from May to September. It is questionable, however, whether this favorable condition will be maintained over a prolonged period. (See Fig. 1.)

Field Discoveries

The great drilling activity during the year resulted in the discovery of three new fields in the San Joaquin Valley, as well as many extensions

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of proven fields and the discovery of deeper production. The discovery of the three new fields is credited to geophysical prospecting and probably represents the culmination of several years' work. About 30 geophysical parties were maintained in California during the year. Withdrawals from reserves were approximately 238,000,000 bbl., and it is estimated that additions to reserves by new discoveries of the year will be almost twice that amount. Since 1928 each year's withdrawals have been greater than additions to reserves, but 1937 established a new trend, which may be continued over a prolonged period because of increased geophysical prospecting and better interpretation of data secured.

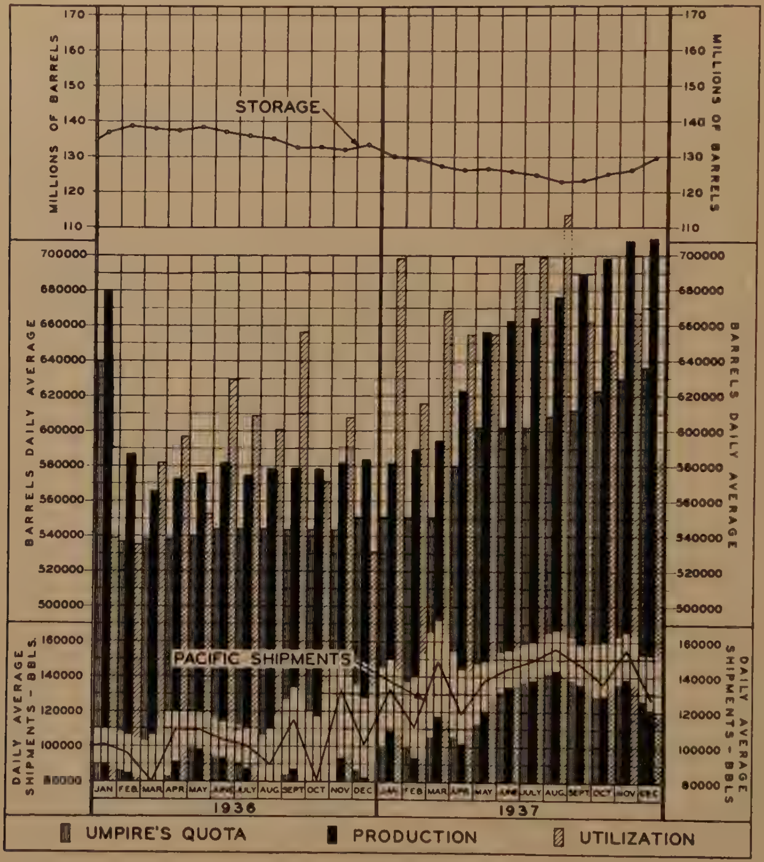

FIG. 1.

San Joaquin Valley

The most important oil discovery in California during the year was that of the Union Oil Co. at Rio Bravo, sec. 34/28/25, four miles northwest of the Greeley field. The discovery well produced at the rate of 1400 bbl. per day of 39.6° gravity oil, through an $\frac{8}{64}$-in. bean, with 1950 lb. tubing pressure and 2000 lb. casing pressure. Gas was produced at the rate of 625 M cu. ft. per day. The well is 11,302 ft. deep and produces from the Vedder sand in the Lower Miocene. It is the deepest producing well in the State of California and inaugurates an era of deep drilling which will undoubtedly make 12,000-ft. holes a relatively common practice. Furthermore, this deep drilling opens possibilities of securing deeper production in many of the old fields in the center of this great basin.

The Ohio Oil Co. discovered what is generally considered to be a new field with the completion of its K.C.L.-E-3 well. This was drilled to a depth of 8175 ft. and had an initial production of 2267 bbl. per day, 36.9 gravity and 1700 M cu. ft. of gas. The gravity of the oil and formations penetrated are similar to those of the Ten Section field, but the location is 2 miles northwest of the proven area. It is quite possible that this discovery is the result of a fault accumulation on the northwest plunge of the Ten Section field, rather than an indication of a separate and distinct structure.

In the Arvin district, 14 miles southeast of Bakersfield, the General Petroleum Corporation made tests in its Houchin No. 1 well, which indicated the discovery of another field similar in character to the Mountain View field.

Extensions of Fields.—Careful and conservative development of the Ten Section field, discovered in 1936 by the Shell Oil Co., extended the proven area of this field to approximately 1200 acres. Owing to great curtailment, the thickness of productive sands and the selection of zones of low gas-oil ratio, the field is expected to have a long flowing life, in spite of the fact that porosity of the sands is low. The structure is a symmetrical anticline with major faulting across the axis. This faulting, however, does not interfere with production.

Kettleman Hills Eocene Production

Although production from the Temblor sands in the Kettleman North Dome did not reach the expectations of early estimates, reserves of this field will be greatly augmented by the discovery of Eocene production during 1937. Kettleman North Dome Association's No. 4-18 J well, a deep test on the northeast edge of the field, produced 1172 bbl. of 45.7° gravity oil through a $\frac{50}{64}$-in. bean with 20,467 M cu. ft. gas. The well was subsequently deepened to 11,679 ft., showing another sand section with slight showing of oil, which probably will be productive higher on the structure. The edge discovery indicates that at least 5000 acres on the northwest plunge of Kettleman Hills field will be productive in the Avenal sand (Eocene).

TABLE 1.—*Oil and Gas Production in California in* 1937

Line Number	Field, *County*	Age, Years to End of 1937	Area Proved, Acres		
			Oil	Oil and Gas[a]	Gas
	Los Angeles Basin				
1	Alamitos, *Los Angeles*	10¾		110	
2	Athens-Rosecrans, *Los Angeles*	13¾		285	
3	Brea-Olinda, *Orange*	57		1,259	
4	Coyote East, *Orange*	26¾		682	
5	Coyote West, *Orange*	32		870	
6	Dominguez, *Los Angeles*	14⅓		810	
7	El Segundo, *Los Angeles*	2⅓		900	
8	Huntington Beach, *Orange*	17⅓		1,890	
9	Inglewood, *Los Angeles*	13¼		860	
10	Lawndale, *Los Angeles*	9½	15		
11	Long Beach, *Los Angeles*	16½		1,350	
12	Los Angeles, *Los Angeles*	34¾		840	
13	Montebello, *Los Angeles*	20⅚		1,180	
14	Playa del Rey, *Los Angeles*	8		640	
15	Potrero, *Los Angeles*	10⅓		88	
16	Richfield, *Orange*	18⅚		1,288	
17	Santa Fe Springs, *Los Angeles*	18⅙		1,240	
18	Seal Beach, *Los Angeles*	11½		400	
19	Torrance, *Los Angeles*	15½		3,750	
20	Whittier, *Los Angeles*	35⅔		590	
21	Wilmington, *Los Angeles*	1½	2,100		
	Coastal District				
22	Capitan, *Santa Barbara*	8¼	360		
23	Elwood, *Santa Barbara*	9½		497	
24	Gato Ridge, *Santa Barbara*	5½	600		
25	Padre Canyon, *Ventura*	1¾		100	
26	Moore Ranch, *Santa Barbara*	8			400
27	Rincon, *Ventura*	10¼	390		
28	San Miguelito, *Ventura*	7⅛		310	
29	Santa Barbara, *Santa Barbara*	8¾	80		
30	Santa Maria, *Santa Barbara and San Luis Obispo*				
31	Santa Maria Valley, *San Luis Obispo*	1¾		6,000	
32	Casmalia, *Santa Barbara*	20⅙	850		
33	Cat Canyon East, *Santa Barbara*	26½	1,177		
34	Cat Canyon West, *Santa Barbara*	26½			
35	Arroya Grande, *San Luis Obispo*	27	150		
36	Huasna, *San Luis Obispo*	8	60		
37	Lompoc, *Santa Barbara*	33	2,940		
38	Orcutt, *Santa Barbara*	35		4,390	
39	Summerland, *Santa Barbara*	45	160		
40	Ventura Ave., *Ventura*	21		2,120	
41	Ventura-NewHall, *Ventura and Los Angeles*				
42	Bardsdale, *Ventura*	43		510	
43	Conejo-Oxnard, *Ventura*	43	110		
44	Elsmere Canyon, *Los Angeles*	48	60		
45	Ex-Mission, *Ventura*	62	130		
46	Hopper Canyon, *Ventura*	49	80		
47	Modelo, *Ventura*	39	60		
48	Newhall-Potrero, *Los Angeles*	48	180		
49	Pico Canyon, *Los Angeles*	62	95		
50	Sespe Canyon, *Ventura*	36		460	

[a] Footnotes to column heads and explanation of symbols are given on page 313.

TABLE 1.—(*Continued*)

Line Number	Area Proved Acres	Total Oil Production, Bbl.				Total Gas Production			
						Millions Cu. Ft.			Maximum Daily during 1937, M Cu. Ft.
	Total	To End of 1937	During 1936	During 1937	Daily Average during Nov. 1937	To End of 1937	During 1936	During 1937	
1	110	[1]	662,909	607,251	1,669		[1]		
2	285	32,426,446	803,811	1,254,383	4,432	78,267	1,078	2,513	6,776
3	1,259	159,817,145	2,960,753	2,631,472	6,049	52,069	2,839	1,597	8,732
4	682	77,582,481	909,646	1,376,176	4,504 }	41,047	1,586	1,717	12,438
5	870	74,685,403	3,033,973	2,880,175	9,473 }				
6	810	97,282,137	9,712,179	9,810,196	29,486	155,350	18,119	17,747	59,227
7	900	3,779,103	149,149	3,629,954	19,047	2,689	y	2,689	14,753
8	1,890	259,284,480	13,247,499	13,240,975	36,175	263,600	20,718	17,712	49,673
9	860	106,562,195	4,546,727	5,482,815	15,968	79,167	1,983	3,104	9,635
10	15	508,421	49,307	29,798	96	1,111			
11	1,350	598,420,762	24,994,299	21,618,468	57,770	803,342	20,589	18,095	51,021
12	840	65,403,574	303,778	222,418	547	y	y	y	
13	1,180	103,676,760	3,204,714	3,146,806	7,324	28,462	3,730	3,018	15,277
14	640	41,145,068	4,643,658	3,143,409	7,820	43,546	6,366	3,851	13,102
15	88	2,274,345	112,556	111,313	408	2,706	467	393	1,209
16	1,288	83,058,535	2,443,126	3,095,366	9,102	74,553	2,044	2,354	7,315
17	1,240	433,953,126	16,460,142	15,714,715	41,738	639,870	11,027	10,721	30,912
18	400	[2]79,058,075	2,800,317	2,801,602	7,695	87,884	4,195	4,285	15,862
19	3,750	85,762,187	2,762,150	2,787,162	7,812	60,105	1,218	1,282	3,548
20	590	17,339,630	346,633	347,344	941	366	y	y	y
21	2,100	14,262,377	97,742	14,133,826	61,058	1,357	y	1,357	25,305
22	360	2,314,006	570,727	918,377	3,039	1,117	432	482	1,847
23	497	62,209,089	4,478,732	3,203,510	7,937	53,107	4,393	4,527	13,957
24	600	831,942	x150,527	650,331	1,721		y		
25	400	483,170	108,836	374,334	993	with Rincon			
26	400					5,034	0	0	0
27	390	8,329,895	754,218	1,062,038	3,788	8,694	649	1,472	5,118
28	450	2,583,322	580,170	771,168	2,479	3,565	1,044	2,521	10,271
29	80	3,035,426	503,939	248,783	606		y	0	
30		138,059,084	1,688,174	3,278,618		6,941	1,502	1,885	4,435
31	6,000	1,683,734	x(61,621)	(1,622,093)[3]	7,591		0		
32	850		(117,990)	(135,702)	237				
33	380		(13,232)	(79,962) }	1,243				
34	807		(145,806)	(208,322) }			0		
35	150		(95,402)	(39,557)	78				
36	60			Shut down	0		Idle		
37	2,940		(85,521)	(123,065)	394		0		
38	4,390		(988,705)	(1,069,917)	2,955		2		
39	160	3,136,035	12,906	11,748	33				
40	2,120	188,518,384	12,609,878	12,682,663	36,474	670,810	38,701	37,811	115,755
41		57,500,891	1,699,905	1,824,810	5,038				
42	510		(26,392)	48,379	178				
43	110		0	3,200	31				
44	60		0	0	0				
45	130		(14,400)	(13,601)	39				
46	80		(38,129)	(35,160)	82				
47	60		(4,841)	(4,252)	14				
48	180		(43,194)	(76,815)	252				
49	95		(22,866)	(22,235)	64				
50	460		(100,650)	(106,331)	316				

[1] With Seal Beach.

[2] Including Alamitos.

[3] Figures in parentheses are not added in totaling. They cover small fields of which totals are included in groups, the group total only being used in the grand total.

TABLE 1.—(*Continued*)

Line Number	Number of Oil and/or Gas Wells								Depth, Average in Feet		Oil Production Methods at End of 1937				Pressure, Lb. per Sq. In.[d]		
		During 1937		At End of 1937							Number of Wells					Average at End of	
	Completed to End of 1937	Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Oil and Gas[b]	Producing Gas Only	Total Producing	Bottoms of Productive Wells	To Top of Productive Zones	Flowing	Pumping	Gas-lift	Miscellaneous	Initial	1936	1937
1		0	4	6		43		49	9,026	4,635		48	1				
2		6	1	7		86		93	6,815	4,120	6	74	13				
3		0	0	124		287		411	4,200	260		393	18				
4		10	0	23		86		109	4,100	2,450	2	107					
5		2	3	89		53		142	5,910	2,800		142					
6		17	2	37		163		200	6,200	3,800	49	110	41				
7		49	2	2		43		45	7,620	6,800	14	27	4				
8		29	7	89		572		661	4,730	1,900	4	652	5				
9		4	8	94		192		286	4,100	1,850	30	255	1				
10		0	0		6			6	6,500	6,375		6					
11		24	32	2		1,250		1,252	8,470	2,300		1,248	4				
12		0	10	1	109			110	3,500	475		110					
13		7	4	37		202		239	7,012	1,730	5	234					
14		5	14	7		213		220	5,730	3,350	1	219					
15		1	1			10		10	6,710	3,640	1	9					
16		22	1	22		284		306	4,550	2,900		306					
17		3	31	35		663		698	7,850	3,470		662	36				
18		2	0	27		65		92	7,100	4,350	9	74	9				
19		18	9	51		530		581	3,200	2,700		581					
20		0	1	18		157		175	4,200	250		175					
21		335	1	2	317			319	3,648	2,400	220	99					
22		7	0	10	39			49	2,580	1,150	15	34					
23		1	2	6		81		87	4,385	3,164	6	63	18				
24		8		2	8			10	2,550	1,750		10					
25		4				6		6	5,500	4,800	3	3					
26		0	0				4	4	4,493	4,193	4						
27		7	1	2	40			42	3,550	2,500	9	28	5				
28		2				8		8	6,800	5,500	6	2					
29		0	12	2	38			40	2,040	1,965		40					
30																	
31		55	3	1		53		54	5,200	2,000	20	34					
32		0	1	57	13			70	3,900			70					
33		0		25	5			30	3,100			30					
34		0		27	14			41	3,700			41					
35				14	8			22	1,200	800		22					
36		1	1	1				1	3,400	2,311			1				
37		0		29	6			35	2,900	2,200		35					
38		4		93	137			230				230					
39		0		1	7			8	1,260	600		8					
40		19	3	56		270		326	9,720	3,450	123	157	46				
41		18															
42		(1)		5	29			34	1,250	950		34					
43		(2)		53				53	300	100		2		51			
44				23				23	1,242	500		23					
45				3	21			24				24					
46				6	8			14	1,000	2,000		14					
47					14			14	500	180		14					
48		(1)		11	19	1		31	1,505	1,290	1	30					
49				2	34			36	1,810	858		36					
50		(2)	5	16	20			36	1,000	400		36					

TABLE 1.—(*Continued*)

Line Number	Character of Oil, Approx. Average during 1936					Producing Rock						Deepest Zone Tested to End of 1937	
	Gravity A.P.I. at 60° F.												
	Maximum	Minimum	Weighted Average	Sulphur, Per Cent	Base[e]	Name	Age[f]	Character[g]	Porosity[h]	Net Thickness, Average in Feet	Structure[i]	Name	Depth of Hole, Ft.
1	30	23	26		A	Repetto-Puente	Pli-Mio	SH		2,335	A		9,054
2	40	30	35			Repetto-Puente	Pli-Mio	SH		3,410	A		10,389
3	28	15	22			Repetto-Puente	Pli-Mio	SH		3,940	MF		8,201
4	28	18	21			Repetto-Puente	Pli-Mio	SH		900	A		9,084
5	32	27	29			Repetto	Pli	SH		2,100	A		8,144
6	43	26	27			Repetto-Puente	Pli-Mio	SH		3,400	A		10,435
7	17	28	26			Puente	Mio	SH		200	A		8,009
8	27	10	23			Repetto-Puente	Pli-Mio	Cong. SH		2,000	MF		9,054
9	29	16	23			Pico-Repetto-Puente	Pli-Mio	SH		2,950	A		6,508
10	32	26	29			Puente	Mio	SH		125	ML		7,405
11	32	20	25			Pico-Repetto-Puente	Pli-Mio	SH		3,500	A		9,280
12	22	12	15			Repetto-Puente	Pli-Mio	SH		1,600	A		5,084
13	34	14	26			Repetto-Puente	Pli-Mio	SH		2,560	A		8,265
14	26	20	24	2.70		Repetto-Puente	Pli-Mio	SH		1,290	A		7,048
15	45	34	28			Repetto	Pli	SH		395	AF		8,376
16	28	15	21			Repetto-Puente	Pli-Mio	SH		1,450	A		10,496
17	36	27	32			Repetto-Puente	Pli-Mio	SH		3,260	A		11,314
18	30	22	26			Repetto-Puente	Pli-Mio	SH		1,980	A		9,054
19	27	14	19			Repetto-Puente	Pli-Mio	SH		500	A		6,597
20	31	16	24			Repetto	Pli	SH		250	MF		5,040
21	14	17	28	2.47		Repetto-Puente	Pli-Mio	SH			AF		6,814
22	44	20	32			Vaqueros-Sespe	Mio-Olig	SH		350	A		4,071
23	39	34	36			Vaqueros-Sespe	Mio-Olig	SH		600	A		7,157
24	17	13	14			Monterey	Mio	broken shale		800	A		6,510
25	28	29	30			Repetto	Pli	SH		270	AF		7,291
26						Vaqueros	Mio	SH		354	AF		6,912
27	31	25	27			Repetto	Pli	SH		650	A		7,449
28	30	22	27			Repetto	Pli	SH		775	AF		10,030
29	20	17	19			Vaqueros	Mio	SH		75	MF		4,730
30													
31	14	17	16			Monterey	Mio	broken shale SH		210	MU		8,133
32	8	22	9			Monterey	Mio	broken shale SH		350	A		
33	12	16	13			Sisquoe-Monterey	Pli-Mio	broken shale SH		220	AN		
34	12	16	13			Sisquoe-Monterey	Pli-Mio	broken shale SH		200	AN		7,199
35	20	14	14			Monterey	Mio	SH		400	S		4,424
36	18	15	15			Monterey	Mio				A		5,627
37			19			Monterey	Mio				AF		4,310
38	25	10	17			Monterey	Mio	Broken shale			AF		5,815
39	20	11	15			Fernando	Pli	SH			A		
40	33	28	30			Pico-Repetto	Pli	SH			A		10,569
41													
42	32	26	28			Sespe-Eocene	Olig-Eoc	SH			A	Eocene	6,804
43	15	12	15			Vaqueros	Mio	SH			MU		
44	23	14	18			Pico	Pli	SH			MU		2,117
45	28	24	24								MF		
46	32	14	14			Modelo-Vaqueros	Mio	SH			A		2,200
47	30	14	15			Modelo-Vaqueros	Mio	SH			A		1,488
48	19	14	15									Eocene	3,504
49	42	33	38			Modelo	Mio	SH			AF		3,445
50	33	27	28			Sespe	Olig	SH			AF		3,595

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Age, Years to End of 1937	Area Proved, Acres		
			Oil	Oil and Gas[a]	Gas
51	Shiells Canyon, *Ventura*	26		350	
52	Simi, *Ventura*	25		596	
53	Sisar Silver Thread, *Ventura*	52	330		
54	South Mountain, *Ventura*	22		725	
55	Sulphur Mountain, *Ventura*	10	40		
56	Tapo Eureka, *Ventura*	56	170		
57	Temescal, *Ventura*	13	235		
58	Timber Canyon, *Ventura*	39	110		
59	Fresno-Lion Mt., *Ventura*	19	50		
60	Torrey Mt., *Ventura*	41	190		
61	Wiley Mt., *Los Angeles*	50	28		
62	North Coastal Counties				
63	Half Moon Bay, *San Mateo*	51	80		
64	Los Gatos, *Santa Clara*	*y*	20		
65	Sargent, *Santa Clara*	43	60		
	San Joaquin Valley				
66	Belridge, *Kern*	27		3,300	
67	North: deep	7 }		1,700	
68	Shallow	25 }			
69	South	27		1,600	
70	Canal	⅓	*y*	*y*	
71	Arvin, *Kern*	⅓	*y*	*y*	
72	Coalinga, East *Fresno*	37 }		14,724	
73	Coalinga, West *Fresno*	36 }			
74	Coffee Canyon, *Kern*	5		500	
75	Edison, *Kern*	6		1,880	
76	Elk Hills, *Kern*	19		9,600	
77	Fruitvale, *Kern*	10		1,620	
78	Greeley, *Kern*	1	1,500		
79	Kern Front, *Kern*	25	3,360		
80	Kern River, *Kern*	37	9,633		
81	Kettleman Middle, *Kings*	6		950	
82	Kettleman North, *Kings, Fresno*	9		16,510	
83	Lost Hills, *Kern*	28	2,600		
84	McKittrick, *Kern*	40	1,525		
85	Midway Maricopa, *Kern*	36		48,117	
86	McVan, *Kern*	6	300	With Premier	
87	Mountain View, *Kern*	4		2,010	
88	Mount Poso, *Kern*	12	2,245		
89	Premier, *Kern*	11	1,220		
90	Rio Bravo, *Kern*	1⁄12		*y*	
91	Round Mountain, *Kern*	10	1,420		
92	Tejon Ranch, *Kern*	1½		100	
93	Ten Sections, *Kern*	1		1,200	
94	Wheeler Ridge, *Kern*	16	295		
95	Total				
	GAS FIELDS, SAN JOAQUIN VALLEY				
96	Buena Vista Lake, *Kern*	3			1,000
97	Buttonwillow, *Kern*	10			2,000
98	Treco, *Tulare*	3			3,000
99	Semitropic, *Kern*	3			4,800
100	Tracy, *San Joaquin*	2			600
101	McDonald Is., *San Joaquin*	2			1,200
102	Rio Vista, *Solano*	2			5,000
103	Total				

TABLE 1.—(*Continued*)

Line Number	Area Proved Acres	Total Oil Production, Bbl.				Total Gas Production			
						Millions Cu. Ft.			Maximum Daily during 1937, M Cu. Ft.
	Total	To End of 1937	During 1936	During 1937	Daily Average during Nov. 1937	To End of 1937	During 1936	During 1937	
51	350	(8,396,343)	(301,905)	(404,333)	1,222	with S. Mountain			
52	596		(39,213)	(37,899)	106				
53	330		(42,426)	(48,930)	145				
54	725	(19,106,510)	(685,247)	(593,155)	1,591	49,974	2,335	2,785	10,576
55	40		(3,489)	(3,336)	6				
56	170		(11,898)	(10,907)	21				
57	235		(249,254)	(326,254)	905			584*x*	
58	110		(17,324)	(9,790)	25				
59	50		(5,111)	(16,401)	13				
60	190		(51,216)	(52,072)	143				
61	28		(6,397)	(5,475)	11				
62			21,960						
63	80		Shut down		0				
64	20			Abandoned 1918	0				
65	60	142,272	8,363	8,969	26				
66	3,300	57,459,893	4,648,261	6,286,195		126,860			
67	1,700		(3,904,936)	(5,645,731)	16,532		36,606	42,681	138,171
68			(12,027)	(10,976)	8				
69	1,600	(21,340,639)	(731,298)	(629,488)	1,497				
70	*y*	31,575			587				
71	*y*		0	1,467	50				
72	14,724	352,371,542	3,947,681	3,780,226	10,236	1,116	36	23	107
73			2,119,398	1,946,233	5,340				
74	500	with Round Mt.	1,450,486	1,809,282	4,927				
75	1,880	4,714,983	2,023,451	1,545,616	3,891				
76	9,600	142,161,515	3,194,445	3,774,687	10,999	83,975	578	541	1,644
77	1,620	15,111,629	2,902,620	3,166,669	7,924				
78	1,500	531,604		527,100	2,818	1,582	0	1,582	24,595
79	3,360	with Kern River	3,517,544	3,803,136	10,349		0	0	
80	9,633	274,569,421	1,645,180	909,063	2,444		0	0	
81	950	516,123	137,630	49,485	96	12,919	1,891	2,879	11,464
82	16,510	176,393,390	29,148,997	29,078,290	81,619	1,094,924	109,048	115,418	397,602
83	2,600	36,905,789	1,346,757	1,392,338	4,104	with Belridge			1,426
84	1,525	87,047,294	777,420	1,269,640	4,393				
85	48,117	832,777,836	21,481,620	26,402,633	58,814	323,330	14,121	15,747	43,427
86	300	with Mt. Poso	(11,848)	(38,672)	221	0			
87	2,010	28,626,673	9,712,658	6,672,796	15,886	37,187	15,622	8,672	30,432
88	2,245	36,361,502	6,182,760	6,478,386	22,968				
89	1,220	with Mt. Poso	(564,450)	(913,541)	2,095				
90	*y*	127,834		127,833	1,617				
91	1,420	16,690,498	2,504,893	2,978,186	11,118				
92	100			2,088	19				
93	1,200	1,120,892	188,464	932,437	3,411	5,067	2,969	2,098	13,153
94	295	3,467,670	128,962	118,600	312			0	
95	187,494	4,907,379,571	214,773,315	237,200,995	705,385				
96	1,000					1,008	0	1,008	13,271
97	2,000					6,885	780	784	9,491
98	3,000					46	14	32	547
99	4,800					716	0	716	10,736
100	600					2,959	448	2,511	26,341
101	1,200					1,154	0	1,154	15,103
102	5,000					1,237	0	1,237	11,254
103						4,947,810	214,773	345,279	

TABLE 1.—(*Continued*)

	Number of Oil and/or Gas Wells								Depth, Average in Feet		Oil Production Methods at End of 1937				Pressure, Lb. per Sq. In.[d]		
		During 1937		At End of 1937							Number of Wells					Average at End of	
Line Number	Completed to End of 1937	Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Oil and Gas[b]	Producing Gas Only	Total Producing	Bottoms of Productive Wells	To Top of Productive Zones	Flowing	Pumping	Gas-lift	Miscellaneous	Initial	1936	1937
51		(6)	1	15		107		122	602	4,200	4	118					
52					56			56	2,025	1,100		56					
53				3	71			74	1,000	315		74					
54		(2)		5	83			88	3,400	2,200		88					
55				2				2	2,300			2					
56				4	19			23	1,350	500		23					
57		(4)	2		12			12	3,500	3,000		12					
58				1	25			26	1,475	500		26					
59					14			14	830	200		14					
60				1	40			41	2,000	600		41					
61				2	11			13	800	600		13					
62																	
63				11				11				11					
64				13				13				13					
65					9			9				9					
66		15	1														
67		(14)		6		47		53	4,917	8,350	34	9	10				
68				14	3			17	2,500	4,100		17					
69		(1)		104		153		257	4,500	1,000	3	254					
70	1	1	0				1	1	8,175	8,098	1						
71		1				2		2	7,350	7,300	1	1					
72		0	21	249	354			603	2,440	1,860		603					
73		1		139	573			712	1,720	1,300		712					
74		4		1	63			64	1,750	1,350		64					
75		12	15	3		88		91	2,080	2,000		91					
76		5	10	82		170		252	3,900	3,450		252					
77		38	5	5		162		167	3,900	3,000	20	147					
78		10	1	1		10		11	7,880	7,800	11						
79		38	0	17	427			444	2,000	1,700		444					
80		11	3	1,126	944			2,070	850	400		2,070					
81		1	0			3		3	7,900	7,563	3						
82		31	0	30		178		208	7,800	6,200	84	5	89	30			
83		19	3	152	247			399	1,930	1,430		399					
84		9	0	86	226			312	3,700	3,300		312					
85		123	46	1,048		2,567		3,615	3,200	3,000	21	3,594					
86		6	0		13			13	1,200	1,170		13					
87		40	12	1		190		191	5,350	5,200	14	171	7				
88		41	0	42	260			302	1,680	1,600		302					
89		6	0		67			67	2,690	2,577		67					
90		1	0			1		1	11,302	11,249	1						
91		41	1	16	108			124	1,700	1,600		124					
92		3	0			3		3	4,470	4,430	2	1					
93		8	0	1		7		8	8,464	7,850	8				3,500		3,500
94		0	0	7	27			34	2,000	4,150		34					
95											735				4,850		
96		1					5	5	5,219	4,638	5						
97		0					30	30	2,750	2,500	30						
98		0					9	9	2,475	2,450	9						
99		0					24	24	2,275	2,235	24						
100		0	1				6	6	4,885	3,920	6						
101		2					5	5	5,216	5,178	5						
102		15					17	17	4,300	4,129	17				1,725		1,725
103		1,156	273	4,305	4,544	9,006	101	17,956			831	16,736	308	81			

TABLE 1.—(*Continued*)

	Character of Oil, Approx. Average during 1936					Producing Rock						Deepest Zone Tested to End of 1937	
	Gravity A.P.I. at 60° F.												
Line Number	Maximum	Minimum	Weighted Average	Sulphur, Per Cent	Base[e]	Name	Age[f]	Character[g]	Porosity[h]	Net Thickness, Average in Feet	Structure[i]	Name	Depth of Hole, Ft.
51	45	17	30			Sespe	Olig	SH		1,800	D	Eocene	7,423
52	32	42	38			Meganos	Eoc	SH			A		
53	29	10	18			Sespe	Olig	SH			MF		3,934
54	33	19	24			Sespe	Olig	SH		3,200	D		5,922
55	20	16	16			Monterey	Mio	SH			ML		
56	26	20	24			Vaqueros	Mio	SH			A		2,956
57	25	23	24			Modelo	Mio	SH			AF		4,584
58			34			Fernando-Monterey	Pli-Mio	SH			MF		3,300
59			22										
60	35	28	30			Vaqueros-Sespe	Mio-Olig	SH			AF		2,500
61	31	25	28			Modelo	Mio	SH			AF		3,835
62													
63	42	28	40			Monterey	Mio	Broken shale			ML		
64	26	22	23										
65													
66	42	13	27										
67						Temblor Wagon Wheel	Mio-Olig	SH		980	A		9,492
68						Etchegoin	Pli	SH		150	A		
69	27	17	22			Etchegoin	Pli	SH		570	A		
70			37			Monterey	Mio	SH		77	*y*		8,175
71			30		A	Chanac	Pli	SH		50	*y*	Granite	7,928
72	34	12	17			Etchegoin Temblor	Pli-Mio	SH		420	AUP		
73	24	12	16			Etchegoin Temblor	Pli-Mio	SH		420	MUP	Kreyenhagen	4,148
74	17	16	16			Vedder	Mio	SH		400	MF		
75	28	14	18			Kern River Temblor	Pli-Mio	SH		80	ML, MI		
76	38	15	27	0.57		Etchegoin	Pli	SH		450	A		
77	23	15	20	0.60		Etchegoin-Chanac	Pli	SH		900	AF		
78	60	32	32	0.28		Monterey-Stevens	Mio	SH		80	MUF		8,403
79	15	13	13			Etchegoin	Pli	SH		300	MF	Santa Margarita	2,650
80	17	12	14			Kern River	Pli	SH		450	MU		
81	38	52	55			Temblor	Mio	SH		337	A		9,138
82	61	35	38	0.30		Temblor-Avenal	Mio, Eoc	SH		1,600	A		11,746
83	33	14	24			Etchegoin	Pli	SH		500	A	Vaqueros	7,858
84	22	12	17			Etchegoin	Pli	SH		400	AF		6,664
85	30	12	18	0.65		Etchegoin-Maricopa	Pli, Mio	SH		200	MU		9,753
86	14	12	13			Vedder	Mio			30	MF		
87	26	32	30	0.44		Chanac-Sta. Margarita	Pli, Mio			150	MF	Temblor	8,419
88	17	15	15			Vedder	Mio			80	MF	Granite	3,130
89	17	12	14			Etchegoin	Pli			113	MF		6,070
90			39			Vedder	Mio	S	25	53	A*x*		11,302
91	22	15	16			Temblor	Mio	SH		100	MF		3,763
92	40	20	23			Miocene	Mio	SH		40	AM		
93	36	31	34	0.37	A	Stevens	Mio	SH	16	614	A		8,984
94	31	22	25			Etchegoin, Sta. Margarita	Pli, Mio	SH		2,150	A		7,154
95													
96						Etchegoin	Pli	SH		120	A		7,957
97						Etchegoin	Pli	SH		250	D		4,946
98						Etchegoin	Pli	SH		25	A		11,466
99						Etchegoin	Pli	SH		40	A		5,698
100						Cretaceous	Cre	SH					7,000
101						Eocene	Eoc	SH		38	A		5,298
102						Eocene	Eoc	S		171	AF		7,029
103													

The Greeley field, discovered by the Standard Oil Co. in 1936, was extended to 1500 proven acres during 1937. Development to date indicates that deposition of sands is very irregular, owing to shore-line sedimentation. One dry hole was drilled within the proven area, a very unusual condition in California fields.

The Mount Poso field was extended to the northeast by the Ring Petroleum Co. Seventeen wells drilled during the year indicate that 320 acres will be productive of 15° gravity oil at shallow depths.

The Round Mountain field was extended to the east by the Eastmont Oil Co. Production is obtained from Miocene sands sealed on the east by complicated faulting. Development to date indicates that 200 acres will be productive of heavy oil.

The proven area of the North Belridge area in the Wagon Wheel sand (Eocene) was extended for a distance of 1½ miles by the completion of The Texas Company's J. D. Martin No. 1 well, which was completed for 2707 bbl. of 32.6 gravity oil.

Ventura District

San Miguelito Field.—Development during the year indicates that the San Miguelito field, a small productive area west of the Ventura Avenue field, is a portion of that prolific structure. This development, which will not be rapid, will add to the acreage in reserve of the Ventura Avenue field.

TABLE 2.—*Summary of Drilling Operations in California*

	County	Location			Total Depth, Ft.	Name of Well
		Sec.	Twp.	Rge.		
1	Kern	34	28	25	11,302	Kernoo-1-34
2	Kern	14	30	25	8,175	K. C.L.-E-3
3	Fresno	18	21	17	10,753	4-18-J.
4	Kern	27	31	29	7,360	Houchin No. 1
5	Fresno	14	21	15	5,594	Assoc. No. 1
6	Fresno	3	17	15	6,480	S. P. Land No. 1
7	Kern	36	29	27	5,937	F. & P. No. 1
8	Kern	17	26	19	2,670	Beer No. 4
9	Kern	33	11	19	4,468	Tejon No. 1
10	Kern	3	36	26	8,405	K. C. L. 10
11	Kern	23	26	20	10,056	Arkelo No. 1
12	Kern	2	30	28	5,789	Routzong No. 1
13	Kern	8	27	24	9,591	K. C. L. A-1
14	Humboldt	22	3H	1W	5,737	Eureka No. 2
15	Madera	27	12	15	6,388	Gill No. 1
16	San Benito	5	12	4	6,921	Murphy No. 1
17	Sutter	2	15	1	5,200	Buttes No. 4
18	Los Angeles	13	4	13	4,038	Am. E. B. No. 1
19	Los Angeles	19	3	13	7,595	O'Dea No. 10
20	Los Angeles	26	4	17	6,472	Rancho S. F. No. 1
21	Los Angeles	22	3	14	8,044	Badger No. 1
22	Los Angeles	9	4	10	8,608	Harbeson No. 1
23	Los Angeles	25	2	15	9,486	Fox Hills

Santa Maria Valley Field.—Since the discovery of the Santa Maria Valley field, development has been increasing, so that 44 wells have been completed, proving approximately 6000 acres to be productive. All production obtained from this field is from brown shale and sand of the middle Miocene formation that overlies the basement complex unconformably. There is considerable irregularity in the producing horizons, with initial productions varying between 50 and 6000 bbl. of 16° gravity oil. Wells are spaced one to 10 acres, and it is expected that the development will proceed in an orderly and moderately steady manner for several years. Reserves of the field are expected to approximate 70,000,000 barrels.

Los Angeles Basin

Discoveries in the Los Angeles Basin during the year were of minor significance, and additions to reserves were mainly due to extensions of and discoveries of deeper zones in proven areas.

Signal Hill Field.—A fault-line extension of the Signal Hill field (Long Beach) was discovered by the Hildon Oil Co. in the northwest end of the

TABLE 2.—(*Continued*)

	Deepest Horizon Tested	Drilled by	Initial Production per Day		Choke or Bean, Fractions of an Inch	Pressure, Lb. per Sq. In.		Remarks
			Oil, U. S. Bbl.	Gas, M. Cu. Ft.		Casing	Tubing	
1	Vaqueros-Mio	Union Oil Co.	1,400	625	8/64	2,000	1,950	Discovery well, Rio Bravo field
2	Monterey-Mio	Ohio Oil Co.	2,267	1,700	1	1,575	420	Discovery well, Canal field
3	Avenal-Eoc	Kettleman N.D.A.	1,172	20,467	50/64	2,550	2,400	Discovery, Avenal zone, Kettleman Hills
4	Chanac-Pli	General Pet. Co.	123		5/8	Packer	110	Discovery, Arvin field
5	Temblor-Mio	Jacalitos Oil Co.						Dry hole
6	Temblor-Mio	Western Gulf Oil Co.	100					Nearly dry
7	Sta. Margarita-Mio	Wilshire Oil Co.						Dry
8	Vaqueros-Mio	Amerada Oil Co.	12					Overlap production
9	Chanac-Pli	Universal Con. Oil Co.	46	300	16/64	1,000	890	New field
10	Monterey-Mio	Superior Oil Co.						Dry, outpost, Greeley field
11	Monterey-Mio	Arkelo Oil Co.						Dry
12	Sta. Margarita	Standard Oil Co.						Dry
13	Miocene	Cont. Oil Co.	25					Indicates new field
14	Pliocene	Texas Company		1,000	1	2,175		New gas field
15	Panoche-Cre	Seaboard Oil Co.						Dry
16	Miocene	Assoc. Oil Co.						Dry
17	Cretaceous	Buttes Oil Ltd.		15,000				New gas field
18	Alamitos-Pli	Hilldon Oil Co.	700		1	150	20	Discovery Ext. Long Beach
19	Puente-Mio	Barnsdall Oil Co.	1,500	3,286	31/64	1,240	820	Deep zone discovery, Rosecrans
20	Miocene	Barnsdall Oil Co.	400	3,000	40/64	400	250	New discovery, Newhall field
21	Puente-Mio	Standard Oil Co.						Dry
22		Shell Oil Co.						Dry hole
23	Schist-Jur	Superior Oil Co.						Dry

	In Proven Fields	Wildcats
Number of wells drilling Dec. 31, 1937		
Number of oil wells completed during 1937	1,170	4
Number of gas wells completed during 1937	12	
Number of dry holes completed during 1937		

field by the completion of its well A.M.F.B. No. 1 for 960 bbl. of 24.2° gravity oil from the Alamitos zone. Three additional wells have since been completed with less initial production. The productive area of the extension is estimated at 100 acres.

Newhall Field.—The Newhall field, adjacent to the area where oil was first discovered in California, was discovered by the Barnsdall Oil Co. when it completed its Rancho San Francisco No. 1 for 255 bbl. of 34.1 gravity oil from Miocene formations. The type of structure and the extent of productive area are as yet unknown.

Rosecrans Field.—The Barnsdall Oil Co. proved the existence of a new deep zone in the Rosecrans field, but later developments showed that the productive area was of limited extent.

Dominguez Field.—The Union Oil Co. proved the existence of an eighth Collender zone in the Dominguez field, although production was small. Additional development will be necessary to prove the extent and value of this new discovery.

Wilmington Field.—Wilmington was the most active field in the Los Angeles Basin during the year, with 280 wells drilled. Development shows that the structure is an irregularly shaped dome, with faulting transverse to the principal axial trend. The structure is rather flat and production comes from Lower Pliocene and Upper Miocene strata. Five productive zones have been discovered. The gravity of the oil ranges from 12° to 31°. The average initial production is approximately 500 bbl. per day, but wells cannot be produced at capacity because of sand trouble. A large portion of the field is within the city limits of Long Beach, which has not as yet been opened for drilling. It is expected that when permits are granted for this drilling, the greatest activity in California will occur in this area during 1938. The total productive area is estimated at 4000 acres, with reserves of 170,000,000 barrels.

El Segundo Field.—El Segundo field, discovered in September 1935, had very little development immediately subsequent to discovery, because of the uncertainty of obtaining commercial production. Activity was revived, however, in 1937, by the completion of The Texas Company's Security No. 1 well for 4800 bbl., on the west side of the structure. The oil occurs at the base of the sediments between the Miocene shale and solid schist. Both the base of the conglomerate and the underlying schist where fractured act as a reservoir. Development indicates that approximately 800 acres will be proven, with a total reserve of 13,000,000 bbl. Because of the lack of adequate reservoir, decline in production of the wells is very rapid.

Increased Activity

Increased activity of the industry during the year, in comparison with previous years, is shown in Table 3.

DRILLING AND PRODUCTION METHODS

Specialists are beginning to study everything from pumping and drilling equipment to cement and rotary mud. Special problems are being solved with efficient methods where only partial solution was formerly considered sufficient. Many are apprehensive of the replacement of the older generalized equipment by the newer specialized machines, whose lack of adaptability is occasionally felt. Probably they can never entirely supplant the older designs for that reason. Some of the innovations in drilling are:

1. Carefully engineered design of the entire drilling machine including as much unitization as practical; and standardization of parts and piping.
2. The use of heavy drill collars, permitting greater drilling speed without sacrifice of straight hole.
3. Controlled pressure drilling is being used successfully in some fields and is reported to have a very beneficial effect. This is believed to be due to the prevention of penetration of the producing sand by drilling fluid.
4. Chemical treatment of wells to remove wax, mud cake, lime crusts, etc., has received considerable attention; and some progress has been made. The belief is gaining ground that this has a definite place in the industry when known preparations are used and accurate records are kept. Secret preparations and anxiety for business, for a while, gave such treatment a questionable reputation.
5. Gravel packing of the hole between the perforated liner and the formation has received a great impetus during the year. It shows promise in holding running sands and shifting formations, but the economies of the operation and its proper field of usefulness is not yet completely proved.

TABLE 3.—*Activities in California Petroleum Industry*

Year	Drilling Notices Filed	Drilling Wells Abandoned	Producers Completed	Increase or Decrease, Per Cent	Initial Production of New Wells, Daily Average	
					Per Well	Total
1929	1,256	314	910		1,437	1,307,496
1930	918	254	755	−17	775	584,521
1931	329	238	246	−67	1,481	364,434
1932	279	191	184	−25	852	156,823
1933	596	163	248	+35	1,105	274,104
1934	631	247	449	+81	1,190	534,508
1935	986	347	710	+37	954	677,320
1936	1,102	320	786	+11	471	370,227
1937 (est.)	1,640	326	1,157	+47	567	656,019

6. The fundamental nature and handling of rotary mud continues to receive attention and really scientific foundations are being approached. Economic considerations will follow.

7. Some progress has been made in the testing and handling of cement. Previously this was considered strictly the problem of the manufacturer. The building up of test and result data by the user should ultimately result in benefit to both. The selection of the proper cement for the job and the method of handling it, based on test data, has already been a great benefit to the user.

The most important problem in the producing side of the industry is that of producing deep wells satisfactorily and economically after the end of their gas-lift period. This cannot be considered as solved; but here also specialized equipment is doing its part.

Many scientific devices are being used in the diagnosis of the producing properties of the well. No one of these gives complete data, but in conjunction with each other, have proved of immense value.

Probably the most important characteristic of the producing well is the productivity index, which determines the production capacity and hence the type and size of the producing equipment. Recording pressure gauges at the pump or base of the tubing record the fluid head; a device on the echo principle records the fluid level as measured from the surface. A pump dynamometer records the load at the pump and its filling characteristics. Surface dynamometers determine rod and surface equipment loads.

By these means, the proper pump size, depth, length of stroke, and rate of pumping may be determined. These factors and the surface loads determine the surface equipment. The required equipment may be of standard or special size, but is being fitted to the demand.

Special producing means such as intermitters, gas displacement pumps, plunger lifts, etc., are being used where their fitness is indicated. Hydraulic pumps are finding their field of greatest usefulness in deep wells where productivity is not too high and where casing sizes are adequate.

SUMMARY

Drilling activity during the year was greater than that for any year in the history of the California oil industry. Undoubtedly 1938 will be an active year, limited by economic conditions and increasing lack of proven drilling locations. Average depth of wells will tend to increase and many deep tests of 12,000 ft. will be drilled in the San Joaquin Valley. Wildcat activity in the state is expected to continue at the same rate as in 1937.

During the year, average daily market demand increased because of abnormal conditions, and it is estimated that the demand for 1938 will be less than in the closing months of 1937.

Oil and Gas Development in Colorado in 1937

By C. E. Shoenfelt,* Member A.I.M.E.

The outstanding development in the Rocky Mountain region for 1937 was the discovery of oil on the Wilson Creek dome in Rio Blanco County, Colorado, in the Morrison formation of Jurassic age. This discovery opens up a vast territory to exploitation and definitely establishes the western slope of Colorado as one of the region's more important oil areas. In former years, a large number of structures on the western slope were tested dry in Upper Cretaceous rocks but are now believed to hold possibilities in older formations, and a number of such structures are in line for drilling in 1938.

Table 1.—*Oil and Gas Production in Colorado in* 1937

Line Number	Field, *County*	Age, Years to End of 1937	Area Proved, Acres				Total Oil Production, Bbl.			
			Oil	Oil and Gas[a]	Gas	Total	To End of 1937	During 1936	During 1937	Daily Average during Nov. 1937
1	Berthoud, *Larimer*	8		510		510	46,142	3,446	4,825	13
2	Boulder, *Boulder*	35	400			400	632,039	5,951	9,125	25
3	Florence, *Fremont*	76	9,000			9,000	13,402,815	67,961	57,694	180
4	Ft. Collins, *Larimer*	14	400			400	2,057,134	23,391	15,432	42
5	Garcia, *Las Animas*	11			640	640				
6	Greasewood, *Weld*	7	200			200	439,637	18,924	5,878	23
7	Hamilton (Moffat), *Moffat*	14	400			400	5,341,156	150,327	143,474	404
8	Hiawatha, *Moffat*	10			3,180	3,180				
9	Iles, *Moffat*	13	600			600	6,382,295	1,164,540	1,036,108	2,654
10	Mancos Creek, *Montezuma*		40			40	3,816	218	0[1]	0
11	Model, *Las Animas*	9			4,380	4,380				
12	Rangely, *Rio Blanco*	18	320			320	462,561	28,774	30,723	98
13	Thornburg, *Rio Blanco*	13			350	350				
14	Tow Creek, *Routt*	13	200			200	1,534,550	63,636	62,500	500
15	Walden, *Jackson*	10	320			320	156,886	0	0	0
16	Wellington, *Larimer*	13	1,000			1,000	4,626,431	95,218	73,464	190
17	Price, *Archuleta*	3	200			200	161,020		161,020[2]	657
18	Total		13,080	510	8,550	22,140	35,246,482	1,622,386	1,600,243	

[a] Footnotes to column heads and explanation of symbols are given on page 313.
[1] Field abandoned during 1936.
[2] Includes oil produced and stored in 1936.

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TABLE 1.—(*Continued*)

Line Number	Total Gas Production, Millions of Cubic Feet			Number of Oil and/or Gas Wells							Depth, Average in Feet		Oil Production Methods at End of 1937		Pressure, Lb. per Sq. In.[d]		
					During 1937		At End of 1937						Number of Wells			Average at End of	
	To End of 1937	During 1936	During 1937	Completed to End of 1937	Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Gas Only	Total Producing	Bottoms of Productive Wells	To Top of Productive Zone	Flowing	Pumping	Initial	1936	1937
1	516.4	40.8	49.6	6	0	1		3	1	4	2,940	2,920		3	600	95	90
2				54	0	1		8		8		2,000		8			
3				1,203	0	1		105		105		2,200		105			
4				15	0	0		11		11	4,560	4,535		11			
5	3,081.0	197.0	195.0	15	0	0	1		8	8		1,600			12	4	4
6				8	0	0		3		3				3			
7				23	0	0		12		12	3,880	3,860		12			
8	14,626.5	2,785.8	2,494.0	10	0	0	1		10	10	Sand lenses				850	785	770
9				39	2	0		34		34	3,315	3,295	15	19			
10				33	0	0		0		0		375	0	0			
11	64.5	0	0	6	0	0		0		0	1,004	960			12		112
12				52	0	2	1	4		4		600		4			
13	79.2	0	79.2	3	0	0	1		3	3	2,125 3,050	1,975 2,525			725		725
14				17	0	0		15		15		2,600		15			
15				4	0	0				0	5,215	5,110					
16				32	1	0		22		22	4,500	4,480		22			
17				19	0	6		11		11			11				
18	18,367.6	3,023.6	3,530.6	1,539	3	11	4	228	22	250			26	202			

Line Number	Character of Oil, Approx. Average during 1937				Character of Gas, Approx. Average during 1937		Producing Rock						Number of Dry and/or Near-dry Holes to End of 1936	Deepest Zone Tested to End of 1937	
	Gravity A.P.I. at 60° F.														
	Maximum	Minimum	Weighted Average	Base[e]	B.t.u. per Cu. Ft.	Gal. Gasoline per M Cu. Ft.	Name	Age[f]	Character[g]	Porosity[h]	Net Thickness, Average in Feet	Structure[i]		Name	Depth of Hole, Ft.
1			38.5	P	1,120	0.09	Hygiene	CreU	S	20	20	A	5	Lakota (CreL)	4,031
2			38.6	P			Pierre	CreU	H			MF	46	Morrison (Jur)	3,497
3			31	P			Pierre	CreU	H			TS	1,097	Fountain (Pen)	1,875
4	37		34.8	P			Muddy-Dakota	CreU	S	12	25	A	4	Dakota (CreU)	4,995
5					1,131	2.00	Benton	CreU	H			D	7	Morrison (Jur)	1,392
6			42	P			Muddy	CreU	S	9	35	A	6	Morrison (Jur)	7,040
7			41	P			{ Dakota { Sundance	CreU Jur	S S	18 14	 20	 D	11	Sundance (Jur)	4,490
8					1,080		Wasatch	Eoc	S	*y*	*x*	D		Mesa Verde (CreU)	7,577
9			37	P			Sundance	Jur	S	9	20	D	5	Sundance (Jur)	3,447
10			40	P			Mancos	CreU	S	*y*	*y*	ML	30	Dakota (CreU)	1,280
11					Inert[3]		Santa Rosa (?)	Tri	S	19	50	D	2	Fountain (Pen)	2,010
12	52	42		P			Mancos	CreU	H			A	46	Mississippian	7,173
13							Dakota Sundance	CreU Jur	S S	15 15	35 500	 D	0	Sundance (Jur)	3,095
14			35	P			Mancos	CreU	H			A	2	Gneiss[5]	5,310
15			50	P	[4]		Muddy-Dakota	CreU	S	14	90	AF	2	Morrison (Jur)	5,258
16			37.4	P			Muddy-Dakota	CreU	S	12	20	A	8	Sundance (Jur)	4,992
17			40	P			Dakota	CreU	S	*y*	*y*	A	8	Dakota (?)	
18													1,279		

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[3] Inert; 7.9 per cent helium.

[4] Wells produce large quantities of CO_2 gas—not utilized at present.

[5] Oldest sedimentary formation tested Thaynes (Triassic).

The Wilson Creek well is on the SW. SE. NW. of sec. 35, 3 N., 94 W., and was completed in the Morrison sand at 6664 to 6704 ft. for an initial production of 500 bbl. of oil per day. The well was drilled through the underlying Sundance sand before completion, and, although the cores recovered showed oil saturation, on test the sand produced only water.

Wilson Creek is a large circular dome, 5 miles in diameter, formed in beds of lower Mesa Verde (Upper Cretaceous) age. The structural closure is more than 1000 ft. The surface elevation at the well site is 8051 ft. above sea level.

Three deep tests were drilled in the eastern part of Colorado in 1937, all of which were failures. The Gulf Oil Corporation's No. 1 Union Pacific-Smith in Lincoln County was drilled 100 ft. in Arbuckle lime and was abandoned at 7096 ft., a dry hole.

Morgan, Flynn and Cobb drilled a well in Kiowa County, in the Nee-No-Shee district, which failed to find oil in the Arbuckle lime and was abandoned at 5540 feet.

The Indian Territory Illuminating Oil Co., which was active in eastern Colorado in 1936, drilled a well in the southeastern part of the state, in the Big Bend district of Bent County, in 1937. This well reached a depth of 5651 ft. before abandonment and tested the Arbuckle.

The completion of these three dry holes, combined with unfavorable tests in 1936, have dampened the enthusiasm of the wildcatter for this area and at the close of the year only one well was in active operation. It is a test being drilled by the Gulf Oil Corporation near Kit Carson, but it seems quite certain that several wells will be drilled in eastern Colorado in 1938, one of which will be on the Continental Oil Company's Cotton-

TABLE 2.—*Summary of Drilling Operations in Colorado in* 1937

	County	Location			Total Depth, Ft.	Deepest Horizon Tested	Drilled by	Initial Production per Day	Remarks
		Sec.	Twp.	Rge.				Oil, Bbl.	
1	Archuleta	21	32 N	4 E	1295	Dakota	Continental		Dry hole
2	Bent	2	21 S	48 W	5651	Arbuckle	I. T. I. O.		Dry hole
3	Kiowa	1	17 S	50 W	6175	Arbuckle	Gulf Oil Corp.		Dry hole
4	Kiowa	6	20 S	46 W	5540	Arbuckle	Morgan & Flynn		Dry hole
5	Lincoln	19	15 S	53 W	7096	Arbuckle	Gulf Oil Corp.		Dry hole
6	Moffat	19	9 N	99 W	3007	Wasatch	Kerlyn Oil Co.		Dry hole
7	Moffat	1	11 N	100 W	3761	Upper Cretaceous	Kerlyn Oil Co.		Dry hole
8		17	11 N	100 W	3460	Wasatch	Kerlyn Oil Co.		Dry hole
9	Rio Blanco	35	3 N	94 W	6898	Sundance	Calif-Texas	500	

	In Proved Fields	Wildcats
Number of wells drilling Dec. 31, 1937	0	9
Number of oil wells completed during 1937	3	20
Number of gas wells completed during 1937	1	0
Number of dry holes completed during 1937	8	19

wood block north of Lamar. This block was assembled in 1928–1929 and is on an excellent surface structure. Most of the large lease blocks are being held intact pending the outcome of other contemplated tests in Colorado and western Kansas.

ACKNOWLEDGMENT

The author is indebted to Mr. W. T. Nightingale, of The Mountain Fuel Supply Co., and Mr. A. E. Brainerd, of Continental Oil Co., for valuable assistance in the preparation of this report.

Oil and Gas Development in Illinois in 1937

By Alfred H. Bell,* Member A.I.M.E.

(New York Meeting, February, 1938)

The year 1937 has been outstanding in the history of the Illinois oil industry. During the course of the year the state's daily production has been trebled, increasing from 12,000 bbl. per day at the beginning to 37,000 bbl. per day at the end, and the year's total, 7,426,000 bbl. is 66 per cent above the previous year's production of 4,475,000 bbl. The production in January was 368,000 bbl.; in December it was 1,085,000. Production from the old fields increased slightly. Most of the new production is from fields in the central part of the Illinois Basin, an area that for many years was considered unfavorable to the occurrence of oil and gas. The principal producing horizon of the new fields is the McClosky "sand," an oolitic limestone in the Ste. Genevieve formation of lower Mississippian age.

Although development has not yet gone far enough to permit accurate estimates of oil reserves in the new fields, it is believed that they are of the order of 100,000,000 barrels.

The following are the oil fields discovered in 1937 listed in order of amount of daily production at the end of the year; Noble (Richland County), Clay City, including Southeast Clay City (Clay and Wayne counties), Patoka (Marion County), New Centralia (Clinton County), Olney (Richland County), Cisne (Wayne County), Beecher City (Fayette County), and Rinard (Wayne County). One gas field, the Russellville, in Lawrence County, was discovered in 1937. For locations of the new fields see Fig. 1. A generalized geologic column for Illinois, showing producing horizons in the new fields, is given in Fig. 2.

The total productive area of the new fields at the end of 1937 was 1712 acres, in which 230 wells were producing. Thirty-five dry holes were drilled within ¼ mile of producing wells. At the end of the year there were 19 drilling wells, 28 rigs standing, 18 rigging up and 4 new locations in these fields.

In the whole state 447 wells were completed, of which 284 were oil producers and three gas producers. Total initial daily production of

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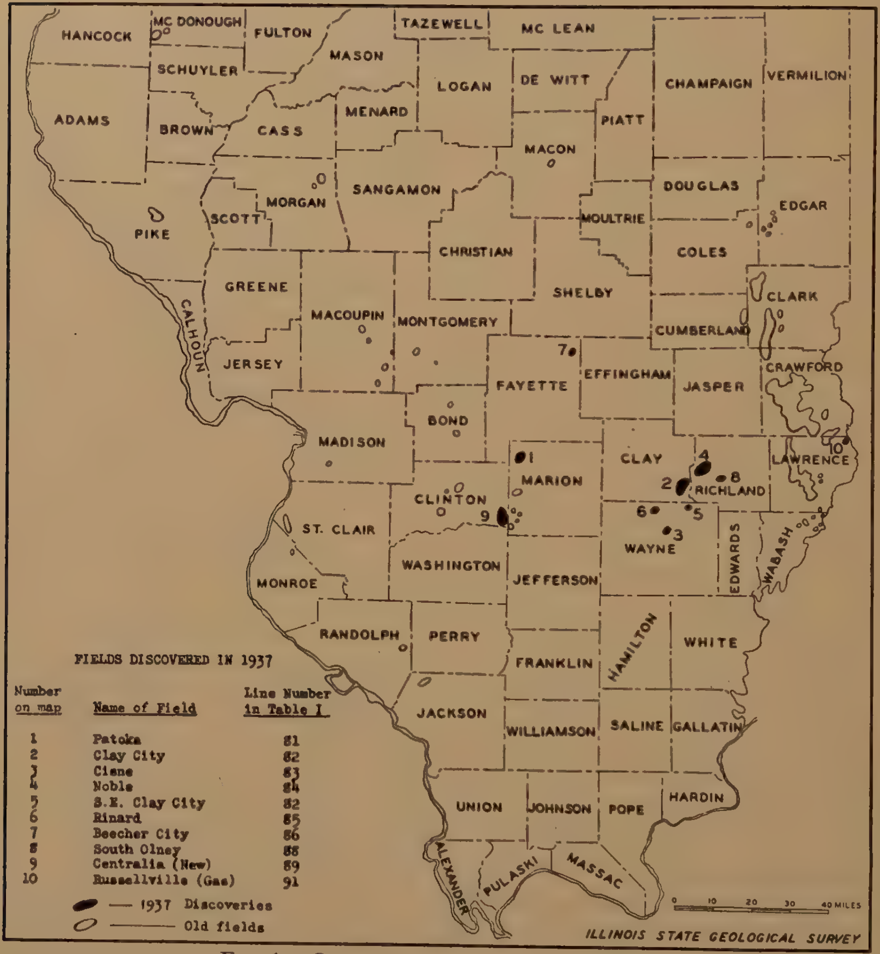
* Geologist and Head of the Oil and Gas Division, Illinois State Geological Survey, Urbana, Illinois.

the oil wells was 78,499 bbl., an average of 276 bbl. per well. At the end of the year the average production per well in the new fields was slightly more than 100 bbl. per day, as compared with 0.8 bbl. per well per day in the old fields.



FIELDS DISCOVERED IN 1937

Number on map	Name of Field	Line Number in Table I
1	Patoka	81
2	Clay City	82
3	Ciene	83
4	Noble	84
5	S.E. Clay City	82
6	Rinard	85
7	Beecher City	86
8	South Olney	88
9	Centralia (New)	89
10	Russellville (Gas)	91

● — 1937 Discoveries
○ ——— Old fields

FIG. 1.—OIL AND GAS FIELDS OF ILLINOIS.

Total footage drilled was 902,795 ft. in all wells and 581,141 in producing wells. If the average cost of drilling is assumed to be $4.50 per foot, there was an investment in drilling of a little more than $4,000,000. The new fields produced up to the end of the year about 2,900,000 bbl. Half of the new wells began to produce after Oct. 1, and their average age at the end of the year was only about three months. Posted price at the end of the year was $1.35 per barrel, but a considerable amount of oil from the new fields was priced at $1.26. Assuming an average price for the year of $1.30, returns from oil from the new fields amounted to $3,770,000. The production in the old fields was approximately

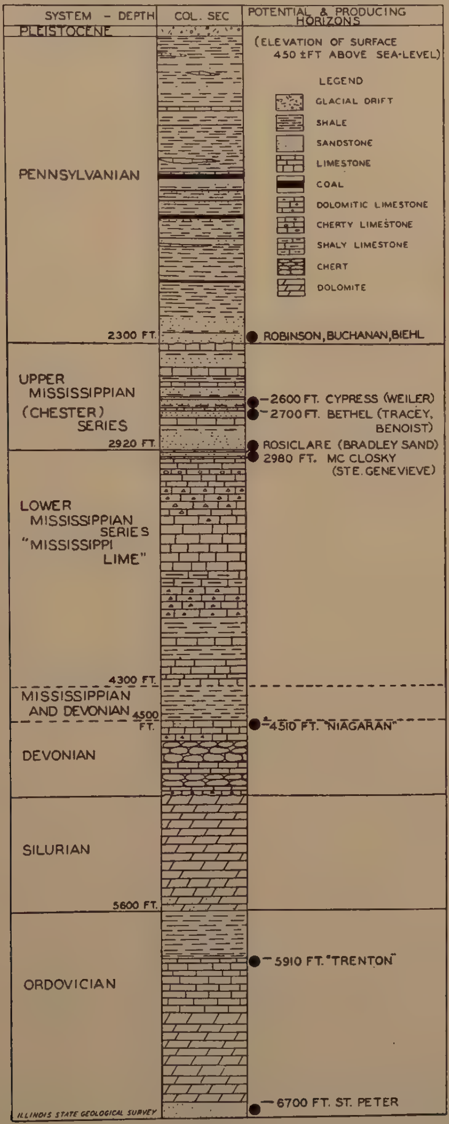

SYSTEM - DEPTH
COL. SEC
POTENTIAL & PRODUCING HORIZONS
PLEISTOCENE
(ELEVATION OF SURFACE 450 ±FT ABOVE SEA-LEVEL)
LEGEND
GLACIAL DRIFT
SHALE
SANDSTONE
LIMESTONE
COAL
DOLOMITIC LIMESTONE
CHERTY LIMESTONE
SHALY LIMESTONE
CHERT
DOLOMITE
PENNSYLVANIAN
2300 FT.
ROBINSON, BUCHANAN, BIEHL
UPPER MISSISSIPPIAN (CHESTER) SERIES
2920 FT.
2600 FT. CYPRESS (WEILER)
2700 FT. BETHEL (TRACEY, BENOIST)
ROSICLARE (BRADLEY SAND)
2980 FT. MC CLOSKY (STE. GENEVIEVE)
LOWER MISSISSIPPIAN SERIES "MISSISSIPPI LIME"
4300 FT.
MISSISSIPPIAN AND DEVONIAN
4500 FT.
4510 FT. "NIAGARAN"
DEVONIAN
SILURIAN
5600 FT.
ORDOVICIAN
5910 FT. "TRENTON"
6700 FT. ST. PETER
ILLINOIS STATE GEOLOGICAL SURVEY

FIG. 2.—GENERALIZED GEOLOGIC COLUMN, NEW ILLINOIS BASIN FIELDS IN CLAY, RICHLAND AND WAYNE COUNTIES.

4,526,000 bbl., valued at approximately $6,100,000, for which the average price was $1.35. This gives a total value of $9,870,000 for all of the oil produced in Illinois in 1937.

Geophysical methods of exploration, especially the reflection seismograph method, are being depended upon to a large extent by the major oil companies active in the Illinois Basin. The number of seismograph crews operating in the state has varied from about 10 to 15 throughout

TABLE 1.—*Oil and Gas Production in Illinois*

Line Number	Field, *County*	Age, Years to End of 1937	Area Proved, Acres			Total Oil Production, Bbl.	
			Oil	Gas	Total	To End of 1937	During 1936
1	Warrenton-Borton, *Edgar*	31	100	0	100	28,400±	1,100
2	Westfield (Parker Twp.), *Clark, Coles*	33	9,000	55	9,055	*x*	*x*
3			850	75	925	*x*	*x*
4			9,000	0	9,000	*x*	*x*
5			1,500	0	1,500	*x*	*x*
6	Siggins (Union Twp.), *Cumberland, Clark*	31	3,580	75	3,655	*x*	*x*
7			3,135	55	3,190	*x*	*x*
8			435	15	450	*x*	*x*
9			855	105	960	*x*	*x*
10	York, *Cumberland*		310	40	350	*x*	*x*
11	Casey, *Clark*	30	1,925	55	1,980	*x*	*x*
12			190	15	205	*x*	*x*
13			400	0	400	*x*	*x*
14			1,525	15	1,540	*x*	*x*
15	Martinsville, *Clark*	30	710	155	865	*x*	*x*
16			15	20	35	*x*	*x*
17			275	35	310	*x*	*x*
18			105	0	105	*x*	*x*
19			170	0	170	*x*	*x*
20			195	0	195	*x*	*x*
21			5	0	5	*x*	*x*
22	North Johnson, *Clark*	30	1,320	20	1,340	*x*	*x*
23			1,115	0	1,115	*x*	*x*
24			160	0	160	*x*	*x*
25			820	5	825	*x*	*x*
26			215	0	215	*x*	*x*
27	South Johnson, *Clark*	30	1,715	65	1,780	*x*	*x*
28			185	5	190	*x*	*x*
29			295	0	295	*x*	*x*
30			1,675	35	1,710	*x*	*x*
31			845	5	850	*x*	*x*
32	Bellair, *Crawford, Jasper*	30	1,300	5	1,305	*x*	*x*
33			1,165	0	1,165	*x*	*x*
34			315	0	315	*x*	*x*
35			910	0	910	*x*	*x*
36	Clark County Division[1]		19,960	475	20,435	51,912,000±	463,600
37	Main,[2] *Crawford*	31	35,135	515	35,650	*x*	*x*
38			340	0	340	*x*	*x*
39			33,795	510	34,305	*x*	*x*
40			1,000	0	1,000	*x*	*x*
41	New Hebron, *Crawford*	28	1,350	210	1,560	*x*	*x*
42	Chapman, *Crawford*	23	1,045	515	1,560	*x*	*x*
43	Parker, *Crawford*	30	1,310	30	1,340	*x*	*x*
44	Allison-Weger, *Crawford*	*y*	1,075	20	1,095	*x*	*x*
45	Flat Rock,[3] *Crawford*	*y*	1,375	545	1,820	*x*	*x*
46	Birds, *Crawford, Lawrence*	*y*	4,370	115	4,485	*x*	*x*
47	Crawford County Division[4]		45,655	1,945	47,600	142,022,000±	1,546,000
48	Lawrence, *Lawrence, Crawford*	31	24,150	1,550	25,700	*x*	*x*
49			5,015	35	5,050	*x*	*x*
50			2,240	0	2,240	*x*	*x*
51			345	1,095	1,440	*x*	*x*

[1] Total of lines 1, 2, 6, 10, 11, 15, 22, 27, 32.
[2] Includes Kibbie, Oblong, Robinson and Hardinsville.
[3] Includes Swearingen gas.
[4] Total of lines 37, 41, 42, 43, 44, 45, 46.

the year, the average being about 12. Magnetic and gravity surveys are being used to a minor extent to indicate structural trends. A small amount of structure test drilling is also being carried on.

Out of 127 wildcat wells drilled during 1937, 80 (63 per cent) were not located by any scientific means, 27 were located on the basis of seismo-

TABLE 1.—(*Continued*)

Line Number	Total Oil Production, Bbl.		Total Gas Production, Millions of Cu. Ft.				Number of Oil and/or Gas Wells							
								During 1937		At End of 1937				
	During 1937	Daily Average during Nov. 1937	To End of 1937	During 1936	During 1937	Maximum Daily during 1937	Completed to End of 1937	Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Oil and Gas[b]	Producing Gas Only	Total Producing
1	821	2	0	0	0	0	22	0	0	1	13	0	0	13
2	*x*	*x*	*x*	0	0	0	1,616	0	3	48	367	0	0	367
3	*x*	*x*	*x*	0	0	0	185	0	0	*y*	*y*	0	0	*y*
4	*x*	*x*	*x*	0	0	0	1,438	3	0	*y*	*y*	0	0	*y*
5	*x*	*x*	*x*	*x*	0	0	12	0	0	*y*	*y*	0	0	*y*
6	*x*	*x*	*x*	0	0	0	995	0	2	*y*	914	*y*	0	914
7	*x*	*x*	*x*	0	0	0	854	0	0	*y*	*y*	*y*	0	*y*
8	*x*	*x*	*x*	0	0	0	90	0	0	*y*	*y*	*y*	0	*y*
9	*x*	*x*	*x*	0	0	0	192	0	0	*y*	*y*	*y*	0	*y*
10	*x*	*x*	*x*	0	0	0	70	0	0	*y*	44	*y*	0	44
11	*x*	*x*	*x*	0	0	0	532	0	0	16	472	0	0	472
12	*x*	*x*	*x*	0	0	0	41	0	*y*	*y*	*y*	0	0	*y*
13	*x*	*x*	*x*	0	0	0	82	0	*y*	*y*	*y*	0	0	*y*
14	*x*	*x*	*x*	0	0	0	319	0	*y*	*y*	*y*	0	0	*y*
15	*x*	*x*	*x*	0	0	0	213	0	9	*y*	126	0	0	126
16	*x*	*x*	*x*	0	0	0	7	0	0	*y*	*y*	0	0	*y*
17	*x*	*x*	*x*	0	0	0	63	0	0	*y*	*y*	0	0	*y*
18	*x*	*x*	*x*	0	0	0	21	0	0	*y*	*y*	0	0	*y*
19	*x*	*x*	*x*	0	0	0	34	0	0	*y*	*y*	0	0	*y*
20	*x*	*x*	*x*	0	0	0	39	0	0	*y*	*y*	0	0	*y*
21	*x*	*x*	0	0	0	0	1	0	0	*y*	1	0	0	1
22	*x*	*x*	*x*	*x*	*x*	*x*	485	0	9	*y*	448	*y*	0	448
23	*x*	*x*	*x*	*x*	*x*	*x*	296	0	0	*y*	*y*	*y*	0	*y*
24	*x*	*x*	*x*	*x*	*x*	*x*	32	0	0	*y*	*y*	0	*y*	*y*
25	*x*	*x*	*x*	*x*	*x*	*x*	177	0	0	*y*	*y*	*y*	0	*y*
26	*x*	*x*	0	0	0	0	44	0	0	*y*	*y*	*y*	0	*y*
27	*x*	*x*	*x*	*x*	*x*	*x*	534	0	1	*y*	486	*y*	0	486
28	*x*	*x*	*x*	*x*	*x*	*x*	38	0	0	*y*	*y*	*y*	0	*y*
29	*x*	*x*	*x*	*x*	*x*	*x*	59	0	0	*y*	*y*	*y*	0	*y*
30	*x*	*x*	*x*	*x*	*x*	*x*	401	0	0	*y*	*y*	*y*	0	*y*
31	*x*	*x*	*x*	*x*	*x*	*x*	170	0	0	*y*	*y*	*y*	0	*y*
32	*x*	*x*	*x*	*x*	*x*	*x*	485	0	4	*y*	403	0	0	403
33	*x*	*x*	*x*	*x*	*x*	*x*	309	0	0	*y*	*y*	0	0	*y*
34	*x*	*x*	*x*	*x*	*x*	*x*	63	0	0	*y*	*y*	0	0	*y*
35	*x*	*x*	*x*	*x*	*x*	*x*	182	0	0	*y*	*y*	0	0	*y*
36	461,560	1,201	*x*	*y*	*y*	*y*	4,977	3	28	65	3,278	*y*	0	3,278
37	*x*	*x*	*x*	*x*	*x*	*x*	7,319	1	0	153	5,235	*y*	0	5,235
38	*x*	*x*	*x*	*x*	*x*	*x*	68	0	*y*	*y*	*y*	0	0	*y*
39	*x*	*x*	*x*	*x*	*x*	*x*	7,141	7	12	*y*	*y*	*y*	0	*y*
40	*x*	*x*	*x*	*x*	*x*	*x*	108	0	*y*	*y*	*y*	*y*	0	*y*
41	*x*	*x*	*x*	*x*	*x*	*x*	296	1	0	2	180	0	0	180
42	*x*	*x*	*x*	*x*	*x*	*x*	193	0	0	2	75	0	0	75
43	*x*	*x*	*x*	*x*	*x*	*x*	256	1	0	*y*	222	0	0	222
44	*x*	*x*	*x*	*x*	*x*	*x*	146	0	0	*y*	65	0	0	65
45	*x*	*x*	*x*	*x*	*x*	*x*	286	3	1	*y*	154	0	0	154
46	*x*	*x*	*x*	*x*	*x*	*x*	684	0	2	*y*	480	0	0	480
47	1,632,174	4,410	*x*	*y*	*y*	*y*	9,187	13	15	157	6,406	*y*	1	6,407
48	*x*	*x*	*x*	*x*	*x*	*x*	4,388	0	0	*y*	3,304	*y*	*y*	3,304
49	*x*	*x*	*x*	*x*	*x*	*x*	1,231	0	*y*	*y*	*y*	*y*	*y*	*y*
50	*x*	*x*	*x*	*x*	*x*	*x*	475	0	*y*	*y*	*y*	*y*	*y*	*y*
51	*x*	*x*	*x*	*x*	*x*	*x*	243	0	*y*	*y*	*y*	*y*	*y*	*y*

[b] Footnotes to column heads and explanation of symbols are given on page 313.

TABLE 1.—(*Continued*)

Line Number	Depth, Average in Feet: Bottoms of Productive Wells	Depth, Average in Feet: To Top of Productive Zone	Oil Production Methods at End of 1937: Number of Wells: Flowing	Oil Production Methods at End of 1937: Number of Wells: Pumping	Oil Production Methods at End of 1937: Injection into Reservoir[24]	Pressure, Lb. per Sq. In.[25]: Initial	Pressure, Lb. per Sq. In.[25]: Average at End of 1936	Pressure, Lb. per Sq. In.[25]: Average at End of 1937	Character of Oil, Approx. Average during 1937: Gravity A.P.I. at 60° F.[26]: Maximum	Character of Oil, Approx. Average during 1937: Gravity A.P.I. at 60° F.[26]: Minimum	Character of Oil, Approx. Average during 1937: Gravity A.P.I. at 60° F.[26]: Weighted Average	Character of Oil, Approx. Average during 1937: Sulphur, Per Cent	Character of Oil, Approx. Average during 1937: Base[e]	Character of Gas, Approx. Average during 1937: B.t.u. per Cu. Ft.	Character of Gas, Approx. Average during 1937: Gal. Gasoline per M Cu. Ft.
1	215	159	0	13		*x*	*x*	*x*	*x*	*x*	*x*	*y*	*y*		
2			0	367		200±	*x*	*x*	38.4	28.3	34.0	*y*	M	*x*	*x*
3	376	281	0	*y*		*x*	*x*	*x*	*y*	*y*	30.0	*y*	M	*x*	*x*
4	446	334	0	*y*		*x*	*x*	*x*	*y*	*y*	33.5	*y*	M	*x*	*x*
5	2,568	2,265	0	*y*		*x*	*x*	*x*	*y*	*y*	37.0	*y*	M	*x*	*x*
6			0	914	A4	*x*	*x*	*x*	(36.9)	27.4	33.0	*y*	M	*x*	*x*
7	465	367	0	*y*		*x*	*x*	*x*	*y*	*y*	34.0	*y*	M	*x*	*x*
8	562	478	0	*y*		*x*	*x*	*x*	*y*	*y*	(33.6)	*y*	M	*x*	*x*
9	590	556	0	*y*		*x*	*x*	*x*	*y*	*y*	(25.7)	*y*	M	*x*	*x*
10	680	588	0	44		*x*	*x*	*x*	33.9	30.0	(30.3)	*y*	M	*x*	*x*
11			0	472	[27]	*x*	*x*	*x*	37.2	27.2	29.2	*y*	M	*x*	*x*
12	358	263	0	*y*		*x*	*x*	*x*	*y*	*y*	(31.9)	*y*	M	*x*	*x*
13	426	309	0	*y*		*x*	*x*	*x*	*y*	*y*	(30.1)	*y*	M	*x*	*x*
14	505	444	0	*y*		*x*	*x*	*x*	*x*	*y*	(33.6)	*y*	M	*x*	*x*
15			0	126	A2	*x*	*x*	*x*	37.5	30.2	36.8	*y*	M	*x*	*x*
16	411	255	0	*y*		*x*	*x*	*x*	*y*	*y*	*y*	*y*	*y*	*x*	*x*
17	511	449	0	*y*		*x*	*x*	*x*	*y*	*y*	*y*	*y*	*y*	*x*	*x*
18	506	477	0	*y*		*x*	*x*	*x*	*y*	*y*	*y*	*y*	*y*	*x*	*x*
19	1,418	1,340	0	*y*		*x*	*x*	*x*	*y*	*y*	(38.9)	*y*	M	*x*	*x*
20	1,596	1,553	0	*y*		*x*	*x*	*x*	*y*	*y*	*y*	*y*	M	*x*	*x*
21	2,830	2,708	0	1		*x*	*x*	*x*	*y*	*y*	(39.6)	*y*	M	*x*	*x*
22			0	448		*x*	*x*	*x*	36.2	27.2	31.0	*y*	M	*x*	*x*
23	486	416	0	*y*		*x*	*x*	*x*	*y*	*y*	*y*	*y*	*y*	*x*	*x*
24	451	314	0	*y*		*x*	*x*	*x*	*y*	*y*	*y*	*y*	*y*	*x*	*x*
25	508	465	0	*y*		*x*	*x*	*x*	*y*	*y*	*y*	*y*	*y*	*x*	*x*
26	554	534	0	*y*		*x*	*x*	*x*	*y*	*y*	*y*	*y*	*y*	*x*	*x*
27			0	486		*x*	*x*	*x*	35.1	28.5	32.2	*y*	M	*x*	*x*
28	549	392	0	*y*		*x*	*x*	*x*	*y*	*y*	*y*	*y*	*y*	*x*	*x*
29	518	453	0	*y*		*x*	*x*	*x*	*y*	*y*	*y*	*y*	*y*	*x*	*x*
30	570	489	0	*y*		*x*	*x*	*x*	*y*	*y*	*y*	*y*	*y*	*x*	*x*
31	618	598	0	*y*		*x*	*x*	*x*	*y*	*y*	28.5	*y*	M	*x*	*x*
32			0	403	AG5	*x*	*x*	*x*	35.6	27.3	33.7	*y*	M	*x*	*x*
33	726	561	0	*y*		*x*	*x*	*x*	*y*	*y*	(32.4)	*y*	M	*x*	*x*
34	907	817	0	*y*		*x*	*x*	*x*	*y*	*y*	*y*	*y*	*y*	*x*	*x*
35	920	886	0	*y*		*x*	*x*	*x*	*y*	*y*	(37.0)	*y*	M	*x*	*x*
36			0	3,278	[28]	*x*	*x*	*x*	39.6	25.8	33.0	*y*			
37			0	5,235	[29]	425±	*y*	*y*	36.8	25.1	33.0	*y*	M	960	2.5
			0												
38	822	508	0	*y*		*x*	*x*	*x*	*y*	*y*	*y*	*y*	*y*	*x*	*x*
39	960	900	0	*y*	[30]	*x*	*x*	*x*	36.8	25.1	32.8	*y*	M	960	2.5
40	1,416	1,337	0	*y*		*x*	*x*	*x*	*y*	*y*	*y*	*y*	*y*	*x*	*x*
41	975	940	0	180	G2	*x*	*x*	*x*	35.0	24.3	30.1	*y*	*y*	*x*	*x*
42	1,015	995	0	75	AG1	*x*	*x*	*x*	*y*	*y*	*y*	*y*	*y*	*x*	*x*
43	1,025	1,000	0	222		*x*	*x*	*x*	*y*	*y*	*y*	*y*	*y*	*x*	*x*
44	930	912	0	65		*x*	*x*	*x*	30.4	22.6	29.5	*y*	*y*	*x*	*x*
45	945	935	0	154		*x*	*x*	*x*	26.6	20.1	22.5	*y*	*y*	*x*	*x*
46	950	930	0	480	A7	*x*	*x*	*x*	34.1	26.5	31.8	*y*	*y*	*x*	*x*
47			0	6,406	[31]	425±	*x*	*x*	38.6	18.5	32.3	*y*	M	960	2.5
48			0	3,304	A1	650±	*x*	*x*	39.3	26.7	32.9	*y*	M	*y*	2.4
49	1,000	800	0	*y*		*x*	*x*	*x*	*y*	*y*	*y*	*y*	*y*	*x*	*x*
50	1,265	1,250	0	*y*		*x*	*x*	*x*	*y*	*y*	*y*	*y*	*y*	*x*	*x*
51	1,345	1,330	0	*y*		*x*	*x*	*x*	*y*	*y*	*y*	*y*	*y*	*x*	*x*

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[24] Numbers in this column indicate numbers of injection wells.

[25] Pressures in the southeastern Illinois oil fields are estimated bottom hole pressures reported in previous Survey publications.

[26] All gravities given prior to 1936 (except those in parentheses) were from data for the year 1925 furnished by the Illinois Pipe Line Co. Gravities in parentheses are for particular samples; see Illinois State Geol. Survey *Bull.* 54, Table 3. The values have been converted from Baumé to A.P.I. gravities.

[27] G1, A13.

[28] G1, AG5, A19.

[29] G17, AG20,A46.

[30] G17, AG20, A46, W1.

[31] G19, AG21, A53, W1.

graph surveys, 17 on geologic surveys, 3 on a combination of seismograph and geologic data. Of the 80 wells located without scientific means 8 (10 per cent) were producers. All of these eight producers were within 1 to 4 miles of previously discovered production in the Clay City and

TABLE 1.—(*Continued*)

Line Number	Producing Rock						Number of Dry and/or Near-dry Holes to End of 1937	Deepest Zone Tested to End of 1937	
	Name	Age[f]	Character[g]	Porosity[h]	Net Thickness, Average in Feet	Structure[i]		Name	Depth of Hole, Ft.
1	Unnamed	Pen	S	Por	*x*	ML	0	Pen	715
2	See below					D	103	Trenton	2,918
3	Shallow gas sand	Pen	S	Por	36	D	*x*		
4	Westfield lime	MisL	L	Cav	*x*	D	*x*	St. Peter	3,009
5	Trenton (Ord)	Ord	L	Por	*x*	D	*x*		
6	See below					D	28	Dev. limestone	2,010
7	First Siggins sand	Pen	S	Por	*x*	D	*x*		
8	Second and third Siggins sand	Pen	S	Por	*x*	D	*x*		
9	Lower Siggins sand	Pen	S	Por	*x*	D	*x*		
10	York sand	Pen	S	Por	*x*	AM	2		960
11	See below					AM	20	MisL	808
12	Upper gas sand	Pen	S	Por	*x*	AM	5		
13	Lower gas sand	Pen	S	Por	*x*	AM	12		
14	Casey sand	Pen	S	Por	*x*	AM	20		
15	See below					D	5	St. Peter	3,411
16	Shallow sands	Pen	S	Por	*x*	D	1		
17	Casey sand	Pen	S	Por	*x*	D	5		
18	Martinsville sand	MisL	L	Por	*x*	D	1		
19	Carper	MisL	S	Por	*x*	D	1		
20	"Niagaran"	Dev	L	Por	*x*	D	3		
21	Trenton	Ord	L	Por	*x*	D	1		
22	See below					AM	16	Mis	965
23	Claypool sand	Pen	S	Por	*x*	AM	12		
24	Shallow sands	Pen	S	Por	*x*	AM	4		
25	Casey sand	Pen	S	Por	*x*	AM	12		
26	Upper Partlow	Pen	S	Por	*x*	AM	16		
27	See below					AM	29	Mis	1,160
28	Claypool sand	Pen	S	Por	*x*	AM	3		
29	Casey sand	Pen	S	Por	*x*	AM	11		
30	Upper Partlow	Pen	S	Por	*x*	AM	29		
31	Lower Partlow	Pen	S	Por	*x*	AM	10		
32	See below					AM	15	MisL	1,471
33	"500 Ft." sand	Pen	S	Por	*x*	AM	3		
34	"800 Ft." sand	Pen	S	Por	*x*	AM	3		
35	"900 Ft." sand	MisU	S	Por	*x*	AM	12		
36					33±		216		
37	See below	[34]					202	Trenton (Ord)	4,620
38	Shallow sand	Pen	S	Por	*x*	ML	*x*		
39	Robinson sand	Pen	S	Por	25±	ML	171	Trenton (Ord)	4,620
40	Oblong	Mis	S or L	Por	*x*	A, ML	23	Mis	1,479
41	Robinson sand[35]	Pen	S	Por	*x*	ML	5	MisL	2,056
42	Robinson sand	Pen	S	Por	*x*	ML	10	Mis	2,279
43	Robinson sand	Pen	S	Por	*x*	ML	11	Pen?	1,127
44	Robinson sand	Pen	S	Por	*x*	ML	6	Pen	1,041
45	Robinson (Flat Rock)	Pen	S	Por	*x*	ML	9	Pen	1,032
46	Robinson sand	Pen	S	Por	*x*	ML	12	MisL	1,731
47		Pen, Mis	S	Por		ML	257	Trenton (Ord)	4,620
48	See below					A	84	St. Peter	5,190
49	Bridgeport sand	Pen	S	Por	40	A	19		
50	Buchanan	Pen	S	Por	15	A	3		
51	"Gas" sand	MisU	S	Por	15	A	5		

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[34] The Salvage Oil and Gas Co.—W. S. McGrillis No. 3, sec. 25, T. 8 N., R. 13 W., is producing in the "McClosky sand" at a depth of from 1409 to 1415 ft.

[35] The West Union Oil and Gas Co.—Ducommon No. 1, sec. 28, T. 6 N., R. 12 W., is producing in the "McClosky sand" from 1506 to 1528 ft.

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Age, Years to End of 1937	Area Proved, Acres			Total Oil Production, Bbl.	
			Oil	Gas	Total	To End of 1937	During 1936
52			15,960	220	16,180	*x*	*x*
53			4,020	200	4,220	*x*	*x*
54			6,950	0	6,950	*x*	*x*
55	St. Francisville, *Lawrence*	*y*	420	0	420	*x*	*x*
56	Lawrence County Division[5]		24,570	1,550	26,120	221,381,000±	1,995,000±
57	Allendale, *Wabash*	25	1,680	0	1,680	4,272,000±	133,000±
58	Total Southeastern Illinois field[6]		91,855	3,970	95,825	419,615,400±	4,138,700
59	Colmar-Plymouth, *Hancock, McDonough*	24	2,450	0	2,450	2,287,800	153,000
60	Pike County Gas, *Pike*	32[7]	0	8,960	8,960	0	0
61	Jacksonville Gas, *Morgan*	27[8]	30	1,290	1,320	2,100	0
62	Carlinville, *Macoupin*	28[9]	30	50	80	*x*	0
63	Spanish Needle Creek, *Macoupin*	22[10]	0	80	80	0	0
64	Gillespie-Wyen, *Macoupin*	22	40	0	40	*x*	4,758
65	Gillespie-Benld Gas, *Macoupin*	14[11]	0	80	80	0	0
66	Staunton Gas, *Macoupin*	21[12]	0	400	400	0	0
67	Litchfield, *Montgomery*	58[13]	100	0	100	22,000	0
68	Collinsville, *Madison*	28[14]	40	0	40	715	0
69	Ayers Gas, *Bond*	15	0	325	325	0	0
70	Greenville Gas, *Bond*	27[15]	0	160	160	0	0
71	Carlyle, *Clinton*	26	915	0	915	3,317,200±	28,200±
72	Frogtown, *Clinton*	19[16]	300	0	300	*x*	0
73	Sandoval, *Marion*	28	770	0	770	2,630,800±	30,160±
74	Centralia, *Marion*	27	175	0	175	*x*	*y*
75	Wamac, *Clinton, Marion, Washington*	16	250	0	250	372,750±	23,200±
76	Dupo, *St. Clair*	9	670	0	670	910,775	53,100
77	Waterloo, *Monroe*	17[17]	125	0	125	166,000	0
78	Sparta Gas, *Randolph*	20[18]	65	100	165	*x*	0
79	Ava-Campbell Hill, *Jackson*	20[19]	70	370	440	25,000	0
80	Bartelso, *Clinton*	2	93	0	93	91,700±	40,700±
81	Patoka, *Marion*	1	310	0	310	425,000	0
82	Clay City, *Clay, Wayne*	1	842	0	842	1,556,260	0
83	Cisne, *Wayne*	1	30	0	30	20,500±	0
84	Noble, *Richland*	1	470	0	470	947,340	0
85	Rinard, *Wayne*	1	10	0	10	2,100±	0
86	Beecher City, *Fayette*	1	10	0	10	*y*	0
87	Beecher City,[20] *Fayette*	1	10	0	10	100±	0
88	Olney, *Richland*	1	10	0	10	600±	0
89	Centralia (New), *Clinton*	1	20	0	20	5,000±	0
90	Decatur, *Macon*	1[21]	10	0	10	600±	0
91	Russellville Gas, *Lawrence*	1	0	10	10	0	0
92	Total Illinois[22]		99,720	15,785	115,500	432,921,000[23]	4,445,000[23]

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[5] Total of lines 48 and 55.

[6] Total of lines 36, 47, 56, 57.

[7] Abandoned 1930.

[8] Abandoned 1937.

[9] Abandoned 1925±.

[10] Abandoned 1934.

[11] Abandoned 1935.

[12] Abandoned 1919.

[13] Abandoned 1904.

[14] Abandoned 1921.

[15] Abandoned 1923.

[16] Abandoned 1933.

[17] Abandoned 1930.

[18] Abandoned 1900.

[19] Abandoned 1934.

[20] The discovery well was plugged back to the Cypress sand in February 1938.

[21] Wells drilled in 1922 and 1924; first production in 1937.

[22] Total of lines 58 to 91.

[23] The total oil production is the figure furnished by the U. S. Bureau of Mines and is not the exact total of the figures given in the table, which were obtained from other sources.

Noble fields. Of the 47 wildcat wells located by scientific means, 11 (23 per cent) were producers.

NATURAL GAS

There are now two gas fields in Illinois from which gas is marketed off the producing leases, the Ayers field, Bond County, now 15 years old, and the Russellville field, Lawrence County, discovered in 1937. The Ayers field furnishes gas for the town of Greenville. One producing well was drilled in this field in 1937 (see Table 1, line 69). In the Russellville field gas is produced in two wells from sandstones in the Pennsylvanian at depths of 288 and 619 ft., respectively. The gas is transported

TABLE 1.—(*Continued*)

Line Number	Total Oil Production, Bbl.		Total Gas Production, Millions Cu. Ft.				Number of Oil and/or Gas Wells							
								During 1937		At End of 1937				
	During 1937	Daily Average during Nov. 1937	To End of 1937	During 1936	During 1937	Maximum Daily during 1937	Completed to End of 1937	Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Oil and Gas[b]	Producing Gas Only	Total Producing
52	*x*	*x*	*x*	*x*	*x*	*x*	3,017	0	*y*	*y*	*y*	*y*	*y*	*y*
53	*x*	*x*	*x*	*x*	*x*	*x*	684	0	*y*	*y*	*y*	*y*	*y*	*y*
54	*x*	*x*	*x*	*x*	*x*	*x*	957	5	*y*	*y*	*y*	*y*	0	*y*
55	*x*	*x*	*x*	*x*	*x*	*x*	54	0	*y*	*y*	45	*y*	*y*	45
56	2,038,046±	5,584±	*x*	*y*	*y*	*y*	9,174	5	18	59	3,277	*y*	*y*	3,277
57	139,291±	381±	*x*	*y*	*y*	*y*	420	9	6	0	322	*y*	0	322
58	4,278,892±	11,578±	*x*	*y*	*y*	*y*	19,035	30	67	281	13,283	*y*	1	13,284
59	147,809	398	0	0	0	0	475	12	0	71	206	0	0	206
60	0	0	*x*	0	0	0	68	0	0	0	0	0	0	0
61	0	0	*x*	0	0	0	53	0	*y*	*y*	0	0	0	0
62	0	0	*x*	0	0	0	8	0	0	0	0	0	0	0
63	0	0	14.4	0	0	0	7	0	*y*	0	0	0	0	0
64	400	0	0	0	0	0	22	0	0	12	0	0	0	0
65	0	0	135.8	0	0	0	4	0	0	0	0	0	0	0
66	0	0	1,050	0	0	0	18	0	0	0	0	0	0	0
67	0	0	*x*	0	0	0	17	0	0	0	0	0	0	0
68	0	0	0	0	0	0	5	0	0	0	0	0	0	0
69	0	0	143,800	37,047	26,353	*y*	18	1	2	0	0	0	9	9
70	0	0	990	0	0	0	4	0	0	0	0	0	0	0
71	28,200±	77±	0	0	0	0	165	1	3	30	77	0	0	77
72	0	0	0	0	0	0	12	0	0	0	0	0	0	0
73	23,800±	70±	0	0	0	0	122	0	9	*y*	36	0	0	36
74	*y*	*y*	0	0	0	0	22	0	0	*y*	3	0	0	3
75	19,750±	55±	0	0	0	0	103	0	1	*y*	45	0	0	45
76	33,175	106	0	0	0	0	237	0	20	0	25	0	0	25
77	0	0	0	0	0	0	23	0	0	0	0	0	0	0
78	0	0	*x*	0	0	0	20	0	0	0	0	0	0	0
79	0	0	*x*	0	0	0	35	0	0	0	0	0	0	0
80	51,000±	140	0	0	0	0	21	12	1	0	20	0	0	20
81	425,000	2,464	0	0	0	0	93	93	0	0	93	0	0	93
82	1,556,260	7,987	0	0	0	0	80	80	0	0	80	0	0	80
83	20,500±	50	0	0	0	0	3	3	1	0	2	0	0	2
84	947,340	10,033	0	0	0	0	47	47	0	0	47	0	0	47
85	2,100±	36	0	0	0	0	1	1	0	0	1	0	0	1
86	*y*	0	0	0	0	0	1	1	0	0	1	0	0	1
87	100±	0	0	0	0	0	1	1	0	0	1	0	0	1
88	600±	0	0	0	0	0	1	1	0	0	1	0	0	1
89	5,000±	0	0	0	0	0	2	2	0	0	2	0	0	2
90	600±	32	0	0	0	0	2	2	0	0	2	0	0	2
91	0	0	2,288	0	2,288	0	2	2	0	0	0	0	2	2
92	7,426,000[23]	33,026	*x*	*y*	*y*	*y*	20,727	289	104	394	13,925	*y*	12	13,937

east across the state line by a new 3-in. pipe line of the Kentucky Natural Gas Co. to Oaktown, Indiana.

In the new oil fields some gas is produced with the oil, and it is used for power on the leases. Few data are available on the amount of gas produced. The largest initial production reported was 2½ million cu. ft. (estimated) for Ohio Oil Company's Arbuthnot No. 1, the discovery well of the Noble field.

The Wiser Oil Company's Damon Smith No. 1, which opened a northern extension of the Clay City field, had an initial daily production

TABLE 1.—(*Continued*)

Line Number	Depth, Average in Feet		Oil Production Methods at End of 1937			Pressure, Lb. per Sq. In.[25]			Character of Oil, Approx. Average during 1937					Character of Gas, Approx. Average during 1937	
			Number of Wells				Average at End of		Gravity A.P.I. at 60° F.[26]						
	Bottoms of Productive Wells	To Top of Productive Zone	Flowing	Pumping	Injection into Reservoir[24]	Initial	1936	1937	Maximum	Minimum	Weighted Average	Sulphur, Per Cent	Base[27]	B.t.u. per Cu. Ft.	Gal. Gasoline per M Cu. Ft.
52	1,430	1,400	0	y		600±	x	x	y	y	y	y	y	x	x
53	1,580	1,560	0	y		650	x	x	y	y	y	y	y	x	x
54	1,710	1,700	0	y		x	x	x	y	y	y	y	y	x	x
55	1,865	1,843	0	45		600	x	x	37.3	37.3	37.3	y	y	x	x
56			0	3,277	A1		x	x						x	
57	1,460	1,425	0	322	W6, A1	x	x	x	35.9	24.1	35.1	y	y	x	x
58			0	13,283	[32]				39.3	18.5	33.1			y	2.4
59	468	447	0	206	A68	x	x	x	y	y	y	y	y		0
60	275	265	0	0		x	x	x						x	x
61	335	330	0	0		x	x	x	x	x	x	x	x	850	y
62	398	380	0	0		135	x	x	x	x	27.7	x	y	x	x
63	405	305	0	0		y	y	y						y	y
64	670	650	0	0		x	x	x	x	x	30	x	y		
65	555	542	0	0		155	x	x						788	y
66	491	461	0	0		145	x	x						x	x
67	674	664	0	0		x	x	x	x	x	21.7	x	y	x	x
68	1,400	1,305	0	0		x	x	x	x	x	x	x	x	x	x
69	945	940	0	0		335	310	310						1,050	0
70	993	927	0	0		x	x	x							0
71	1,055	1,035	0	77	A28	x	x	x	37.0	34.2	35.2	y	y	x	x
72	957	950	0	0		x	x	x	y	y	31.9	y	y	x	x
73	1,560	1,540	0	36		x	x	x	35.1	32.7	34.5	y	y		
74	1,150	1,130	0	3		x	x	x	35.0	31.0	32.0	x	x		
75	760	720	0	45	W21	x	x	x	30.8	29.3	30.2	y	P		
76	651	601	0	25		x	x	x	y	y	32.7	y	y		
77	460	410	0	0		x	x	x	30.1	29.5	30.0	x	x		
78	857	850	0	0		x	x	x	x	x	x	x	x	x	x
79	798	780	0	0		x	x	x	x	x	x	x	x	x	x
80	1,010	986	0	20		x	x	x	y	y	32.0	y	y	x	x
81	1,440	1,424	0	93		x	x	x	39.8	39.3	39.5	y	y	x	x
82	3,002	2,968	4	76		250	x	y	38.8	38.0	38.5	y	y	x	x
83	3,026	2,990	0	2		x	0	x	y	y	38.5	y	y	x	x
84	2,991	2,961	24	23		450	0	250±	y	y	38.5	y	y	x	x
85	3,154	3,144	0	1		x	0	x	y	y	38.5	y	y	x	x
86	1,503	1,497		1		275	0	x	y	y	36.0	y	y	x	x
87	3,100	3,070	0	1		x	0	x	y	y	37.0	y	y	x	x
88	3,083	3,065	0	1		x	0	x	y	y	38.5	y	y	x	x
89	1,370	1,342	0	2		x	x	x	y	y	39	y	y	x	x
90	2,076	2,020	0	2		x	0	x	y	y	39.5	y	y	x	x
91	310 622	288 619	0 0	0 0		140 261	0 0	x x	x x	x x	x x	x x	x x	947	y
92			28	13,897	[33]										

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[32] G20, AG26, A74, W7.
[33] G20, AG26, A170, W28.

of 200,000 cu. ft. of gas and 1400 bbl. of oil, or a gas-oil ratio of 143 cu. ft. per barrel. The average gas-oil ratio in the Clay City and Noble fields probably does not exceed 200 or 300 cu. ft. per barrel.

Gas discoveries in which the gas is not used outside of the producing leases were made near Longview in Champaign County and near Marissa in St. Clair County (Table 2, line 101). The former well was drilled to the Devonian and plugged back. It was not completed until 1938.

TABLE 1.—(*Continued*)

Line Number	Producing Rock						Number of Dry and/or Near-dry Holes to End of 1937	Deepest Zone Tested to End of 1937	
	Name	Age[f]	Character[g]	Porosity[h]	Net Thickness, Average in Feet	Structure[i]		Name	Depth of Hole, Ft.
52	Kirkwood	MisU	S	Por	30	A	10		
53	Tracey	MisU	S	Por	20	A	11		
54	McClosky	MisL	L	Por	10	A	24		
55	Kirkwood	MisU	S	Por	22	ML	0	Mis	1,900
56							84	St. Peter	5,190
57	Biehl sand	Pen	S	Por	20	AM	49	MisL	2,228
58							610		
59	Hoing sand	Dev	S	Por	21	A	8	St. Peter	720
60	"Niagaran"	Sil	L	Por	10	A	0	St. Peter	893
61	Gas sand	Pen, Mis	S, SL	Por	5	ML	8	Trenton (Ord)	1,390
62	Unnamed	Pen	S	Por	x	A	0	Pen	410
63	Unnamed	Pen	S	Por	x	D	1	Pen	495
64	Unnamed	Pen	S	Por	x	T	14	Trenton (Ord)	2,560
65	Unnamed	Pen	S	Por	x	A	0	Pen	575
66	Unnamed	Pen	S	Por	x	A	0	Trenton (Ord)	2,371
67	Unnamed	Pen	S	Por	x	D	0	Pen	681
68	Trenton	Ord	L	Por	20	ML	0	Trenton (Ord)	1,500
69	Lindley (2d)	MisU	S	Por	5	A	2	MisL	1,150
70	Lindley (1st, 2d)	MisU	S	Por	x	A	0	Mis	1,065
71	Carlyle	MisU	S	Por	20	A	17	Sil	2,620
72	Carlyle	MisU	S	Por	7	D	0	Carlyle y	962±
73	Benoist	MisU	S	Por	20±	D	7	Mis	1,732
74	Dykstra, Wilson, Benoist	Pen, MisU	S	Por	20	D, ML	6	MisL	1,779
75	Petro	Pen	S	Por	20	D	0	Benoist	1,484
76	Trenton	Ord	L	Por, Cav	50	A	0	Trenton (Ord)	819
77	Trenton	Ord	L	Por	50	A	19	Trenton (Ord)	845
78	Sparta gas sand	MisU	S	Por	7	D	5	MisU	985
79	Unnamed	MisU	S	Por	18	A	y	Dev	2,530
80	Carlyle	MisU	S	Por	20	D	3	MisU	1,118
81	Benoist[36]	MisU	S	Por	16	A	18	MisL	1,618
82	Ste. Genevieve[37]	MisL	L	Por	8.7	A	8	MisL	3,197
83	Ste. Genevieve	MisL	S, L	Por	8	A?	1	MisL	3,144
84	Ste. Genevieve	MisL	L	Por	9.7	A	5	MisL	3,098
85	Ste. Genevieve	MisL	L	Por	5	A	0	MisL	3,154
86	Benoist	MisU	S	Por	6			Dev	3,170
87	Niagaran	Dev	L	Por		A?	0	Dev	3,170
88	Ste. Genevieve	MisL	L	Por	7	A	0	MisL	3,083
89	Benoist	MisU	S	Por	26	A	0	MisU	1,384
90	Niagaran	Dev	L	Por	30	N	0	Trenton (Ord)	2,800
91	Pennsylvanian sand Pennsylvanian sand	Pen Pen	S S	Por Por	22 3	A	3	MisL	2,012
92							699±		

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[36] The Adams Oil and Gas Companies Sam Pugh No. 1, sec. 29, T. 4 N., R. 1 E., is producing from the Ste. Genevieve limestone at a depth of 1562 ft.

[37] The Pure Oil Company's Weiler No. 1, sec. 33, T. 3 N., R. 8 E., the discovery well in the Clay City field, produced from the Cypress sandstone until October 1937, when it was drilled deeper to the McClosky sand and the Cypress sandstone was cased off.

TABLE 2.—*Summary of Drilling Operations in Illinois*

Important Wildcats Drilled in 1937

	County	Location			Total Depth, Ft.	Surface Formation	Deepest Horizon Tested	Drilled by	Initial Production per Day		Remarks
		Sec. Survey	Twp. Lat.	Rge. Long.					Oil, U. S. Bbl.	Gas, Millions of Cu. Ft.	
1	Bond.......	16	5 N	3 W	1,087	Pleistocene	Chester	Hempen and Burgess			Dry
2	Bond.......	11	6 N	5 W	3,101	Pleistocene	St. Peter	Huber Drilling Corp.			Dry
3	Christian...	29	12 N	2 W	1,122	Pleistocene	Lower Mississippian	Nokomis Oil Co.			Dry
4	Christian...	36	15 N	2 W	1,964	Pleistocene	St. Peter	Parshall-Graham Oil Co.			Dry
5	Christian...	27	12 N	2 W	3,112	Pleistocene	"Trenton"	Roger Bros. et al.			Dry
6	Clay........	33	3 N	8 E	2,613	Pleistocene	Cypress	Pure Oil Co.	40[1]		
7	Clay........	33	3 N	8 E	2,960	Pleistocene	Ste. Genevieve	Pure Oil Co.	2,642		
8	Clay........	28	3 N	8 E	2,987	Pleistocene	Ste. Genevieve	Wiser Oil Co.	1,400		
9	Clay........	12	2 N	6 E	3,163	Pleistocene	Ste. Genevieve	Benedum Trees Co.			Dry
10	Clay........	8	2 N	8 E	3,057	Pleistocene	Ste. Genevieve	Gordon Oil Co.	1,226		
11	Clay........	29	3 N	8 E	3,067	Pleistocene	Ste. Genevieve	Wicklund Development Co.			Dry
12	Clay........	14	3 N	8 E	3,036	Pleistocene	Ste. Genevieve	Elmer Hupp et al.	25		
13	Clay........	2	3 N	6 E	3,112	Pleistocene	Ste. Genevieve	Leonard Drilling Co.			Dry
14	Clay........	17	3 N	7 E	3,002	Pleistocene	Ste. Genevieve	Jack Shaffer et al.			Dry
15	Clay........	23	3 N	8 E	3,183	Pleistocene	Ste. Genevieve	Wicklund Development Co.			Dry
16	Clay........	29	4 N	8 E	3,234	Pleistocene	St. Louis	Gulf Oil Corp.			Dry
17	Clay........	7	3 N	8 E	3,075	Pleistocene	Ste. Genevieve	C. H. C. Oil Co.			Dry
18	Clay........	31	4 N	8 E	3,072	Pleistocene	Ste. Genevieve	Bonnie Oil Co.			Dry
19	Clinton.....	32	2 N	3 W	1,051	Pleistocene	Cypress	J. E. Newton et al.			Dry
20	Clinton.....	11	1 N	2 W	1,365	Pleistocene	Chester	Carl Willi et al.			Dry
21	Clinton.....	28	2 N	3 W	1,206	Pleistocene	Paint Creek	W. C. McBride Inc.			Dry
22	Clinton.....	12	1 N	2 W	1,361	Pleistocene	Chester	Carl Willi et al.			Dry
23	Clinton.....	13	3 N	1 W	1,504	Pleistocene	Bethel	Patoka Pet. Corp.			Dry
24	Clinton.....	2	1 N	2 W	1,567	Pleistocene	Ste. Genevieve	Adams Oil and Gas			Dry
25	Clinton.....	6	1 N	3 W	1,429	Pleistocene	Ste. Genevieve	Willis et al.			Dry
26	Clinton.....	28	2 N	3 W	1,515	Pleistocene	Lower Mississippian	W. C. McBride Inc.			Dry
27	Clinton.....	4	1 N	2 W	1,521	Pleistocene	Lower Mississippian	Wise and Goldschmidt			Dry
28	Clinton.....	27	3 N	1 W	1,454	Pleistocene	Bethel	Adams Oil and Gas			Dry
29	Clinton.....	2	1 N	1 W	1,384	Pleistocene	Bethel	Adams Oil and Gas	156		
30	Clinton.....	26	3 N	1 W	1,724	Pleistocene	Ste. Genevieve	McClanahan Oil			Dry
31	Clinton.....	3	2 N	4 W	1,235	Pleistocene	Lower Mississippian	W. C. McBride Inc.			Dry
32	DeKalb.....	35	41 N	5 E	4,348	Pleistocene	Pre-Cambrian	Paul Schulte et al.			Dry
33	DeKalb.....	27	42 N	3 E	2,970	Pleistocene	Cambrian	Barton et al.			Dry
34	Edgar......	18	12 N	13 W	500	Pleistocene	Pennsylvanian	Hassett et al.			Dry
35	Edwards....	3	2 S	10 E	4,932	Pleistocene	Lower Mississippian	Leach Brothers			Dry
36	Effingham...	5	7 N	6 E	2,100	Pleistocene	Chester	W. H. Hazlett et al.			Dry
37	Effingham...	5	7 N	6 E	3,150	Pleistocene	Lower Mississippian	Faurot, Mitchell and Hazlett			Dry
38	Effingham...	26	6 N	5 E	4,117	Pleistocene	"Niagaran"	Kingwood and Carter Oil			Dry
39	Effingham...	11	8 N	7 E	2,660	Pleistocene	Ste. Genevieve	Carter Oil			Dry
40	Fayette.....	31	5 N	3 E	172	Pleistocene	Pennsylvanian	O. A. Davis et al.			Dry
41	Fayette.....	16	5 N	3 E	2,292	Pleistocene	Ste. Genevieve	Rush and Milleken			Dry
42	Fayette.....	20	4 N	1 W	1,498	Pleistocene	Chester	Linville, Beaton and Ryer			Dry
43	Fayette	36	7 N	1 W	2,000	Pleistocene	Lower Mississippian	Universal Service Drilling Company			Dry
44	Fayette.....	13	4 N	1 W	1,601	Pleistocene	Ste. Genevieve	C. B. Tull et al.			Dry
45	Fayette.....	35	4 N	1 W	1,609	Pleistocene	Ste. Genevieve	Belcher et al.			Dry
46	Fayette.....	16	7 N	2 E	2,163	Pleistocene	Ste. Genevieve	Oil Development Co.			Dry
47	Fayette.....	12	8 N	3 E	3,100	Pleistocene	"Niagaran"	Carter Oil Co.	57[2]		
48	Fayette.....	15	8 N	3 E	1,503	Pleistocene	Benoist	Carter Oil Co.	200[3]		
49	Fayette.....	24	6 N	1 W	3,155	Pleistocene	Silurian	Benedum Trees			Dry
50	Fayette.....	22	6 N	1 E	1,733	Pleistocene	Ste. Genevieve	Hausmann et al. Adams Oil and Gas			Dry

[1] Cut 8 per cent with salt water.
[2] In 17 hours.
[3] Estimated.

TABLE 2.—(*Continued*)

Important Wildcats Drilled in 1937

	County	Location			Total Depth, Ft.	Surface Formation	Deepest Horizon Tested	Drilled by	Initial Production per Day		Remarks
		Sec. Survey	Twp. Lat.	Rge. Long.					Oil, U. S. Bbl.	Gas, Millions of Cu. Ft.	
51	Greene	25	10 N	13 W	800	Pleistocene	"Trenton"	Witt, Godey, and Robey			Dry
52	Hamilton	22	3 S	7 E	3,452	Pleistocene	Ste. Genevieve	J. G. Buell			Dry
53	Hamilton	32	3 W	5 E	3,324	Pleistocene	Chester	A. H. Carpenter et al.			Dry
54	Jasper	18	7 N	14 W	1,104	Pleistocene	Pennsylvanian	William Goodwin			Dry
55	Jasper	24	8 N	8 E	3,504	Pleistocene	Ste. Genevieve	H. H. Weinert			Dry
56	Jasper	10	7 N	8 E	3,205	Pleistocene	St. Louis	W. R. Anderson et al.			Dry
57	Kane	35	40 N	8 E	670	Pleistocene	St. Peter	Edward Duvall et al.			Dry
58	Lawrence	30	5 N	10 W	622	Pleistocene	Pennsylvanian	Warren Hastings et al.		0.824	
59	Lawrence	30	5 N	10 W	660	Pleistocene	Pennsylvanian	Warren Hastings et al.			Dry
60	Lawrence	30	5 N	10 W	2,012	Pleistocene	Salem	Warren Hastings et al.			Dry
61	Lawrence	30	5 N	10 W	310	Pleistocene	Pennsylvanian	Warren Hastings et al.		0.250	
62	Lawrence	30	5 N	10 W	830	Pleistocene	Pennsylvanian	Warren Hastings et al.			Dry
63	Lawrence	29	5 N	10 W	657	Pleistocene	Pennsylvanian	Warren Hastings et al.			Dry
64	Lawrence	29	5 N	10 W	719	Pleistocene	Pennsylvanian	Warren Hastings et al.			Dry
65	Lawrence	16	3 N	10 W	3,302	Pleistocene	"Niagaran"	Strauss et al.			Dry
66	Madison	24	5 N	8 W	1,987	Pleistocene	"Trenton"	T. C. Havelka			Dry
67	Marion	21	4 N	1 E	1,418	Pleistocene	Bethel	Adams Oil and Gas	52[4]		
68	Marion	27	4 N	1 E	1,679	Pleistocene	Ste. Genevieve	Wiser Oil			Dry
69	Marion	29	4 N	1 E	1,612	Pleistocene	Ste. Genevieve	Adams Oil and Gas	29		
70	Marion	28	4 N	1 E	1,425	Pleistocene	Bethel	Illinois Nat. Oil and Gas	300		
71	Marion	22	4 N	1 E	1,707	Pleistocene	Chester	Ray Brown et al.			Dry
72	Marion	32	4 N	1 E	1,616	Pleistocene	Ste. Genevieve	Adams Oil and Gas			Dry
73	Marion	1	3 N	2 E	2,515	Pleistocene	Lower Mississippian	Texas Co.			Dry
74	Marion	4	4 N	3 E	3,671	Pleistocene	"Niagaran"	Carter Oil			Dry
75	Marion	18	4 N	1 E	1,725	Pleistocene	Ste. Genevieve	Ralph Ayers et al.			Dry
76	Marion	25	3 N	2 E	2,439	Pleistocene	Ste. Genevieve	Helmrich and Payne Inc.			Dry
77	Marion	3	3 N	1 E	1,575	Pleistocene	Chester	Roy Benoist			Dry
78	Marion	17	3 N	2 E	2,500	Pleistocene	Lower Mississippian	Target Drilling Co.			Dry
79	Marion	18	3 N	1 E	1,706	Pleistocene	Ste. Genevieve	Shell Pet. Corp.			Dry
80	Marion	33	4 N	1 E	1,530	Pleistocene	Chester	Palmer et al.			Dry
81	Marion	33	4 N	1 E	1,717	Pleistocene	Ste. Genevieve	J. Alexander et al.			Dry
82	Marion	33	4 N	1 E	1,477	Pleistocene	Bethel	J. Alexander et al.			Dry
83	Marion	33	4 N	1 E	1,482	Pleistocene	Bethel	J. Alexander et al.			Dry
84	Mason	22	23 N	7 W	1,000	Pleistocene	"Niagaran"	Werner Brothers			Dry
85	Perry	5	6 S	1 W	5,257	Pleistocene	St. Peter	Howard Forester			Dry
86	Pike	24	5 S	3 W	750	Pleistocene	"Trenton"	Super Oil Co.			Dry
87	Randolph	31	4 S	5 W	1,003	Pleistocene	Chester	Tom Cain et al.			Dry
88	Richland	8	3 N	9 E	2,990	Pleistocene	Ste. Genevieve	Ohio Oil Co.	1,996		
89	Richland	34	4 N	9 E	3,010	Pleistocene	Ste. Genevieve	Mammoth Oil and Refining Co.	1,501		
90	Richland	12	3 N	8 E	3,099	Pleistocene	Ste. Genevieve	Keith and MacMahon			Dry
91	Richland	22	3 N	10 E	3,252	Pleistocene	Ste. Genevieve	Neely et al.			Dry
92	Richland	16	3 N	9 E	2,961	Pleistocene	Ste. Genevieve	Southern Ill. Pet. Co.	145		
93	Richland	27	4 N	9 E	3,007	Pleistocene	Ste. Genevieve	C. L. McMahon			Dry
94	Richland	14	3 N	8 E	3,043	Pleistocene	Ste. Genevieve	Robinson and Gordon	92		
95	Richland	8	2 N	10 E	3,235	Pleistocene	Ste. Genevieve	Wiser Oil Co.			Dry
96	Richland	28	3 N	9 E	3,046	Pleistocene	Ste. Genevieve	Mammoth Oil and Refining Co.	250		
97	Richland	5	3 N	14 W	3,248	Pleistocene	Ste. Genevieve	Hollingsworth			Dry
98	Richland	18	3 N	10 E	3,083	Pleistocene	Ste. Genevieve	Frost et al.	50		
99	Richland	31	5 N	9 E	3,200	Pleistocene	Ste. Genevieve	Kingwood and McMahon			Dry
100	Rock Island	28	20 N	2 E	1,353	Pleistocene	Ordovician	Rockdale Oil and Gas			Dry
101	St. Clair	36	3 S	6 W	800	Pleistocene	Chester	W. A. Holt			Dry[5]
102	St. Clair	18	1 S	7 W	2,013	Pleistocene	"Trenton"	A. J. Colgan et al.			Dry
103	Shelby	14	10 N	6 E	2,384	Pleistocene	Ste. Genevieve	J. A. English et al.			Dry
104	Wabash	27	1 N	12 W	1,480	Pleistocene	Pennsylvanian	Patton Oil Co.	20		
105	Wabash	27	1 N	12 W	1,610	Pleistocene	Chester	Coastal Producing Co.			Dry
106	Wabash	7	1 N	11 W	1,510	Pleistocene	Pennsylvanian	Mahutska Oil			Dry

[4] Natural flow through ¼-in. choke.

[5] Small gas production, used for heating one building.

ACIDIZING IN THE NEW BASIN FIELDS

Almost all of the wells drilled in the Clay City, Cisne and Noble fields have been acidized. Wells having a small thickness of oil saturation or saturation with low permeability are treated before the well is put on production. Wells with high initial productions, which were not acidized at the time of completion, have been acidized when the daily production declined considerably. In almost every well treated production was increased to some extent, varying from slight increases up to fourfold. The wells are treated with 1000 to 4000 gal. of acid.

IMPROVED RECOVERY METHODS IN THE OLD FIELDS

The slow adoption of improved recovery methods in the old fields is due partly no doubt to the intense interest and activity in the new fields of the state.

TABLE 2.—(*Continued*)

Important Wildcats Drilled in 1937

	County	Location			Total Depth, Ft.	Surface Formation	Deepest Horizon Tested	Drilled by	Initial Production per Day		Remarks
		Sec.	Twp.	Rge.							
		Survey	Lat.	Long.					Oil, U. S. Bbl.	Gas, Millions of Cu. Ft.	
107	Wabash.....	28	1 N	13 W	1,863	Pleistocene	Pennsylvanian	Joe Young et al.			Dry
108	Wabash.....	7	1 N	11 W	2,225	Pleistocene	Ste. Genevieve	Adams Corners Oil Co.			Dry
109	Wabash.....	17	1 N	12 W	1,560	Pleistocene	Pennsylvanian	George Randolph et al.			Dry
110	Wabash.....	18	1 N	12 W	1,644	Pleistocene	Chester	Cecil Keneipp			Dry
111	Washington.	22	1 S	4 W	1,002	Pleistocene	Chester	Sunflower Oil Co.			Dry
112	Washington.	22	1 S	5 W	990	Pleistocene	Bethel	Sunflower Oil Co.			Dry
113	Washington.	36	1 N	2 W	1,666	Pleistocene	Ste. Genevieve	Milliken et al.			Dry
114	Wayne......	26	1 N	7 E	2,987	Pleistocene	Ste. Genevieve	Pure Oil Co.	100		
115	Wayne......	26	2 N	8 E	3,066	Pleistocene	Ste. Genevieve	Myers and Fitzpatrick	5[6]		
116	Wayne......	33	2 N	7 E	3,154	Pleistocene	Ste. Genevieve	Benedum and Trees	50		
117	Wayne......	30	2 N	8 E	3,040	Pleistocene	Ste. Genevieve	Andy Bruner			Dry
118	Wayne......	11	1 S	7 E	3,412	Pleistocene	Ste. Genevieve	Mammoth Oil and Refining Co.			Dry
119	Wayne......	27	2 N	8 E	3,040	Pleistocene	Ste. Genevieve	Duncan Oil	583		
120	Wayne......	21	2 N	5 E	3,313	Pleistocene	St. Louis	Benedum and Trees			Dry
121	Wayne......	12	1 N	6 E	3,314	Pleistocene	Ste. Genevieve	Benedum and Trees			Dry
122	Wayne......	28	2 N	7 E	3,085	Pleistocene	Ste. Genevieve	Benedum and Trees			Dry
123	Wayne......	31	2 S	6 E	3,042	Pleistocene	Ste. Genevieve	F. R. Washburn Pet. Corp.			Dry
124	Wayne......	33	2 N	7 E	3,280	Pleistocene	Ste. Genevieve	Benedum and Trees			Dry
125	Wayne......	4	1 N	7 E	3,216	Pleistocene	Ste. Genevieve	Midwest Development Co.			Dry
126	White......	5	4 S	8 E	3,405	Pleistocene	Ste. Genevieve	Johnson and Cozart			Dry
127	Will........	25	35 N	12 E	2,063	Pleistocene	Cambrian	Nelson et al.			Dry

	In Proven Fields	Wildcats
Number of wells drilling Dec. 31, 1937..........	20	14
Number of oil wells completed during 1937..........	262	22
Number of gas wells completed during 1937..........	1	2
Number of dry holes completed during 1937..........	56	104

[6] Per hour.

TABLE 3.—*Summary of Drilling and Initial Production in Illinois for* 1937

County	Number of Wells Drilled in 1937			Total Initial Production		Footage Drilled in 1937	
	Total Completed	Total Producing				Total	Producing Wells
		Oil	Gas	Oil[a]	Gas[b]		
Bond	5	0	1		1.000[e]	7,102	951
Christian	3	0		0		7,237	0
Clark	7[c]	3	[d]	9		3,484	2,387
Clay	91	75		39,710[f]		268,963	219,314
Clinton	29	15		1,165[g]		34,979	14,559
Coles	1	0		0		355	0
Crawford	20[c]	13		160		21,764	14,956
DeKalb	2	0		0		7,318	0
Edgar	1	0		0		500	0
Edwards	1	0		0		4,932	0
Effingham	4	0		0		12,027	0
Fayette	11	2		300[h]		20,826	4,603
Greene	1	0		0		800	0
Hamilton	2	0		0		6,776	0
Hancock	2	0		0		1,184	0
Jasper	3	0		0		7,813	0
Kane	1	0		0		670	0
Lawrence	13	5	2	118	1.074	18,352	10,178
McDonough	15	12		50		6,607	5,332
Madison	1	0		0		1,987	0
Marion	122	93		6,499[i]		169,632	124,073
Mason	1	0		0		1,000	0
Perry	1	0		0		5,257	0
Pike	1	0		0		750	0
Randolph	1	0		0		1,003	0
Richland	60	48		27,293[j]		180,788	143,651
Rock Island	1	0		0		1,353	0
St. Clair	2	0		0		2,813	0
Shelby	1	0		0		2,384	0
Wabash	19	9		340		29,699	13,381
Washington	3	0		0		3,658	0
Wayne	20	9		2,855[k]		63,160	27,756
White	1	0		0		3,405	0
Will	1	0		0		3,095	0
Total for State	447	284	3	78,499	2.074	902,795	581,141

[a] Barrels.

[b] Millions of cubic feet.

[c] One pressure well.

[d] Two wells producing gas, which is used on the lease.

[e] Estimated.

[f] Clay City field.

[g] Bartelso, 886 bbl.; Centralia (new), 276 bbl.; Carlyle field, 3 bbl.

[h] Beecher City field.

[i] Patoka field.

[j] Noble field, 27,243 bbl.; Olney field, 50 bbl.

[k] Cisne field, 222 bbl.; S.E. Clay City field, 2133 bbl.; Rinard field, 500 bbl.; total initial production for new fields, 77,819 bbl.

Acidizing.—In Lawrence County, out of 15 wells that were acid-treated, eight yielded increases in production, one was a new well with initial daily production after acidizing of 40 bbl., and six gave no results in increased production. The total daily production of the eight wells before acid treatment was 16 bbl.; after treatment, 110 bbl., a sixfold increase. The usual charge was 1000 gal. of acid. The producing strata treated in all of these wells was the McClosky oolitic limestone (Ste. Genevieve formation, lower Mississippian series). In the Dupo field, St. Clair County, one well was acid-treated and its production increased from 5 to 12 bbl. per day. The producing stratum is the Kimmswick (Trenton) limestone in the Ordovician.

Air Pressuring.—The air and gas repressuring plants in operation in 1936 continued during 1937 and four new air repressuring operations were begun with a total of 36 input wells.

Water-flooding.—Little new water-flooding was undertaken during 1937. Two of the uncontrolled water-flooding operations in the Allendale field, Wabash County, reported substantial increases in production. The water-flooding operation in the Carlyle field, Clinton County, begun in 1934, has been stopped.

PETROLEUM CONFERENCE

The fifth annual petroleum conference of Illinois-Indiana, held at Robinson, May 29, 1937, was attended by over 300 oil men, including representatives of all the principal oil-producing states. The program consisted of discussion of exploratory methods, development and operating problems. The fifth annual mineral industries conference at Urbana,

TABLE 4.—*Number of Wells in the New Fields, with Acreage*
DECEMBER 31, 1937

Field	Producing Wells	Dry Holes[a]	Drilling Wells	Rigs Standing	Rigging Up	Locations	Acres
Patoka	93	18	4	3	1	0	310
Clay City	80	8	3	7	4	4	842
Rinard	1	0	0	0	0	0	10
Noble	47	5	12	18	13	0	470
Cisne	2[b]	1	0	0	0	0	30
Centralia (new)	2	0	0	0	0	0	20
Beecher City	2	0	0	0	0	0	20
Olney	1	0	0	0	0	0	10
Russellville (gas)	2	3	0	0	0	0	10
Total	230	35	19	28	18	4	

[a] Within ¼ mile of production.

[b] One producing well was abandoned.

TABLE 5.—*Discovery Wells in New Southern Illinois Oil Fields*

Field	County	Company	Date Completed	Farm	Well No.	Location Survey, Tp., Range	Total Depth, Ft.	Producing Formation		Initial Production, Bbl.
								Depth, Ft.	Name	
Patoka..............	Marion	Adams Oil & Gas	1-27-37	Merryman	1	21-4N-1E	1,418	1,391	Benoist	52
Clay City..........	Clay	Pure Oil Co.	2-26-37	Weiler	1	33-3N-8E	2,613	2,608	Cypress	40
Clay City..........	Clay	Pure Oil Co.	5-15-37	B. Travis	1	33-3N-8E	2,960	2,950	McClosky	2,642
Clay City (SE. extension.............	Wayne	Myers & Fitzpatrick	9-10-37	Shannon	1	26-2N-8E	3,066	3,056	McClosky	100
Cisne..............	Wayne	Pure Oil Co.	3- 4-37	Bradley	1	26-1N-7E	2,987	2,982	Ste. Genevieve	100^{a}
Noble..............	Richland	Ohio Oil Co.	8- 2-37	Arbuthnot	1	8-3N-9E	2,990	2,898	McClosky	1,996
Noble (NE. extension)............	Richland	Mammoth Oil Refining Co.	9- 2-37	Heitz	1	34-4N-9E	3,009	2,972	McClosky	1,501
Noble (town).......	Richland	S. Ill. Petr. Co.	10-21-37	Allard	1	16-3N-9E	2,961	2,950	McClosky	145^{b}
Rinard..............	Wayne	Benedum-Trees	10- 5-37	Knapp	1	33-2N-7E	3,154	3,144	McClosky	500^{a}
Beecher City........	Fayette	Carter Oil Co.	12-20-37	Miller	1	12-8N-3E	3,100	3,070	"Niagaran"	57^{c}
Beecher City........	Fayette	Carter Oil Co.	12-31-37	Clow	1	15-8N-3E	1,503	1,497	Benoist	200^{a}
Centralia (new)....	Clinton	Adams Oil & Gas	11-30-37	Schmitz	1	2-1N-1W	1,384	1,348	Benoist	156
Olney..............	Richland	Frost et al.	12-33-37	Farris	1	18-3N-10E	3,084	3,065	McClosky	50

[a] Estimated.
[b] First 12 hours.
[c] In 17 hours.

Oct. 8 and 9, had two half-day programs on oil—one on economic and legal questions, the other on geology and development.

OUTLOOK

With the discovery of oil at a number of widely scattered points in the basin late in 1937 and the early part of 1938, and with a large acreage under lease in the state, including a total of 2,400,000 acres by 12 major companies, there is every indication that drilling activity will increase greatly in 1938 and that other new fields will be discovered.

TABLE 6.—*Illinois Completions for* 1937

Month	Completions	Producing Wells	Month	Completions	Producing Wells
January	5	1	July	27	18
February	6	6	August	49	31
March	9	4	September	92	63
April	15	7	October	76	55
May	14	10	November	71	40
June	22	16	December	61	36
Total				447	287

ACKNOWLEDGMENTS

The writer is indebted to many companies and individuals for furnishing information used in this report. Dr. George V. Cohee of the Survey staff assisted the writer in assembling the data.

Oil and Gas Developments in Indiana in 1937

By Ralph E. Esarey* and M. M. Fidlar†

(New York Meeting, February, 1938)

A marked decrease in drilling during 1937 in Indiana seemed to have no undesirable effect upon the oil and gas industry. Instead, production figures for oil showed a small increase over those for the preceding year, although not so much gas was marketed as in 1936. Drilling activity was centered in proven areas, and the proportion of dry holes to the number of wells drilled decreased somewhat.

During 1937, including old wells drilled to deeper horizons, 134 wells were completed in Indiana, of which 39 were oil wells, 39 gas wells, and 56 dry holes. Nearly 75 per cent of the holes were drilled in proven areas. Of the 36 wells drilled in wildcat areas, only four found commercial production. Wildcat wells were especially numerous in Vigo, Pike, Perry and Spencer Counties. Exploratory drilling activity in Vigo County resulted in part from the drilling of the discovery well in the new Prairie Creek field. In Pike County, wildcat wells were drilled in the search for new supplies of gas to meet the demand in the southwestern portion of Indiana. Drilling in both proven and wildcat areas in Perry and Spencer Counties continued to be heavy, because of the presence of shallow Mississippian sands and the resulting low cost of drilling and equipping. At the end of the year, 42 of the wells started in 1937 were not completed.

Only a few locations were drilled in the old Trenton field, but the wells, many of them 40 years old, continued to furnish a small supply of gas for domestic consumption. Oil production in the Jay County portion of the Trenton area was nearly twice that of 1936, owing in part to a vacuum system installed on several leases. The Harrison County (Laconia) gas field is being developed northward to offset water encroaching from the south. This water in the black shale threatens to put an end to the steady production that this field has furnished for many years.

During 1937, the Oaktown gas field again furnished more gas than any other field, but production in that area showed a marked decrease over the marketed gas for 1936. During the early months of the year, seven wells were completed in the Oaktown field to bring the total number of producing wells to over 40. At present, all the operators in the area are

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Summary presented at the meeting; entire paper received at the office of the Institute March 17, 1938.

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troubled with bottom-hole water in the gas wells. During the spring and summer, three producing gas wells were drilled on a southern extension of the Oaktown gas field.

The Loogootee gas field was extended westward during 1937, and a pipe line was laid into the new area to take this production. The Greens-

TABLE 1.—*Oil and Gas Production in Indiana in* 1937

Line Number	Field, *County*	Age, Years to End of 1937	Area Proved, Acres			Total
			Oil	Oil and Gas[a]	Gas	
1	Alford, *Pike*	18	240	0	960	1,200
2	Blairsville, *Posey-Vanderburgh*	3.7	350	0	0	350
3	Bristow, *Perry*	8	180	0	120	300
4	Cannelburg, *Daviess*	12	6*xx*	0	5*x*	7*xx*
5	Francisco, *Gibson*	8	3*xx*	5*xx*	1*xx*	9*xx*
6	Greensburg, *Decatur*	44	0	0	36,*xxx*	36,*xxx*
7	Harmon, *Pike*	9	20	0	6*xx*	6*xx*
8	Harrison County, *Harrison*	27	0	0	6,200	6,200
9	Hudsonville, *Daviess-Pike*	8	0	0	7*xx*	7*xx*
10	Loogootee, *Daviess-Martin*	37	3*xx*	0	1,8*xx*	2,1*xx*
11	Monroe City, *Knox*	15	4*xx*	*y*	0	4*xx*
12	Oakland City, *Pike*	30	3,1*xx*	0	2*xx*	3,3*xx*
13	Oaktown, *Knox*	7	40	0	800	840
14	Oatesville-Wheeling, *Pike-Gibson*	18	1,9*xx*	0	0	1,9*xx*
15	Prairie Creek, *Vigo*	1	400	0	0	400[1]
16	Riley, *Vigo*	31	640	0	0	640
17	Rock Hill-Grandview, *Spencer*	9	160	0	0	160
18	Shelburn-Graysville, *Sullivan*	26	4,7*xx*	3*xx*	1,0*xx*	6,0*xx*
19	Siosi, *Vigo-Sullivan*	11	750	0	0	750
20	Trenton, "Many"	51	102,*xxx*	25,*xxx*	650,*xxx*	778,*xxx*
21	Tri-County-Somerville, *Pike-Gibson*	12	350	0	80	430
22	Troy-Tell City, *Spencer-Perry*	9	150	700	80	930
23	Union-Bowman, *Pike-Gibson*	21	4,4*xx*	0	5*xx*	4,9*xx*
24	Unionville, *Monroe*	8	0	0	1,4*xx*	1,4*xx*
25	Vanderburgh, *Vanderburgh*	6	580	0	0	580
26	Veale, *Daviess*	11	400	0	0	400
27	Wes tPrinceton, *Bibson*	34	1,6*xx*	0	5*xx*	2,1*xx*
28	Total		124,*xxx*	27,*xxx*	701,*xxx*	852,*xxx*

[a] Footnotes to column heads and explanation of symbols are given on page 313

[1] Not fully outlined.

burg gas field saw little development during 1937, but the area continued to furnish gas for several towns.

The older oil fields of the state continued to produce steadily, and the Siosi pool again led all others in production. A northward extension to the Bowman pool in Pike County was discovered during the year, and seven wells were completed in this area, five of which produced oil and two gas of low B.t.u. content.

TABLE 1.—(*Continued*)

Line Number	Total Oil Production, Bbl.				Total Gas Production, Millions Cu. Ft.				Number of Oil and/or Gas Wells		
										During 1937	
	To End of 1937	During 1936	During 1937	Daily Average during Nov. 1937	To End of 1937	During 1936	During 1937	Maximum Daily during 1937	Completed to End of 1937	Completed	Abandoned
1	3xx,xxx	3,xxx	3,xxx	10	y	3xx	135.x	y	91	0	3
2	103,xxx	45,519	40,381	12x	0	0	0	0	29	5	0
3	52,xxx	5,9xx	5,xxx	y	y	y	y	y	43	1	1
4	y	y	3,xxx	12.5	y	0	0	0	53	1	2
5	7x,xxx	12,778	14,535	5x	1,176	15	76	0.8	35	4	0
6	0	0	0	0	3,5xx	175.x	155.x	1.x	35x	2	15
7	y	0	0	0	y	5x	47.x	y	28	2	0
8	0	0	0	0	3,1xx	29x	25x	y	112	1	3
9	0	0	0	0	y	19x	117.x	0.9	49	2	3
10	2x,xxx	y	0	0	y	9.5	24.x	y	58	4	5
11	y	1,4xx	1,37x	4	y	0	0	0	15	0	0
12	y	25,xxx	27,6xx	92	y	0	0	0	263	0	1
13	45,xxx	11,970	6,2xx	20	1,295.6	678.5	418.2	2.x	70	7	2
14	y	186,217	187,580	5xx	0	0	0	0	253	4	3
15	10,402	0	10,402	2xx	0	0	0	0	4	4	0
16	1xx,xxx	0	417	10	0	0	0	0	33	1	0
17	42,xxx	5,7xx	6,161	y	0	0	0	0	16	0	0
18	6,7xx,xxx	107,6xx	66,906	194	1,xxx	32.x	33	0.1	1,081	6	5
19	2,326,xxx	176,2xx	248,935	7xx	0	0	0	0	81	2	0
20	107,xxx,xxx	25,xxx	39,xxx	y	80x,xxx	200	2xx	y	26,5xx	8	42
21	127,xxx	22,6xx	13,2xx	44	y	y	y	y	74	1	0
22	6x,xxx	12,778	12,xxx	y	273.x	164	109.2	1.x	62	11	1
23	y	130,xxx	155,xxx	45x	y	30	42	y	392	6	6
24	0	0	0	0	18	0	0	0	17	0	0
25	288,570	53,665	44,264	y	0	0	0	0	86	3	3
26	y	21,4xx	16,4xx	45	0	0	0	0	73	0	0
27	1,3xx,xxx	10,2xx	10,9xx	30	y	0	0	0	148	0	1
28	12x,xxx,xxx	857,xxx	913,xxx	y	y	2,13x	1,606	y	30,xxx	75	96

Activity in the Illinois portion of the Eastern Interior Coal Basin seems to be in part responsible for the decrease in drilling activity in Indiana, owing to the fact that many Indiana operators took part in the drilling in Illinois. The Illinois activity reached Indiana in the last half of the year, however, and resulted in the discovery of an oil structure near Prairie Creek, Vigo County. Five wells were completed in this new field,

TABLE 1.—(*Continued*)

	Number of Oil and/or Gas Wells					Depth, Average in Feet		Oil Production Methods at End of 1937				Pressure, Lb. per Sq. In.[d]			Character of Oil, Approx. Average during 1937				
	At End of 1937							Number of Wells					Average at End of		Gravity A.P.I. at 60° F.				
Line Number	Temporarily Shut Down	Producing Oil Only	Producing Oil and Gas[b]	Producing Gas Only	Total Producing	Bottoms of Productive Wells	To Top of Productive Zone	Flowing	Pumping	Miscellaneous	Injection into Reservoir[c]	Initial	1936	1937	Maximum	Minimum	Weighted Average	Sulphur, Per Cent	Base[e]
1	1	7	0	22	29	1,100 1,400	1,080 1,130	0	7	0	0	440	*y*	75	39	36	38	0.2	M
2	3	25	0	0	25	1,031	1,007	0	25	0	0				*y*	*y*	30	0.3	A
3	*y*	30	0	5	35	350	330	0	30	0	0				*y*	*y*	34.7	*y*	A
4	*y*	13	0	0	13	640	630	0	13	0	0				*y*	*y*	*y*	*y*	M
5	3	13	0	7	20	1,450	1,430	0	13	0	0	690	580	*y*	*y*	*y*	29	*y*	M
6	*y*	0	0	23*x*	23*x*	907	886	0	0	0	0	300	115	105					
7	2	0	0	7	7	1,125	1,110	0	0	0	0	450	*y*	35					
8	*y*	0	0	38	38	680	650	0	0	0	0	90	*y*	*y*					
9	0	0	0	15	15	660	650	0	0	0	0	275	120	175					
10	0	0	0	13	13	540	532	0	0	0	0	250	130	125					
11	0	7	0	0	7	1,240 1,560	900 1,225 1,475 1,535	0	7	0	0	*y*			*y*	*y*	*y*	*y*	M, P
12	0	26	0	0	26	1,107 1,126	1,085 1,112	0	26	0	0				*y*	*y*	2*x*	*y*	M
13	3	8	0	39	47	610 802	580 790	0	8	0	0	325	2*xx*	2*xx*	*y*	*y*	35	0.2	M
14	12	202	0	0	202	1,270 1,290 1,360 1,740	1,250 1,270 1,340 1,725	0	202	0	0				*y*	*y*	36	0.3	M
15	0	4	0	0	4	2,174	2,132	2	2	0	0				*y*	*y*	40	*y*	P
16	0	1	0	0	1	1,625	1,615	0	1	0	0				*y*	*y*	50	*y*	P
17	0	7	0	0	7	1,320	1,310	0	7	0	0				*y*	*y*	38	0.2	M
18	*y*	349	0	12	361	325 560 667 775 810 2,285	298 545 640 730 800 2,270	0	1*xx*	0	G2*xx*	*y*	*y*	*y*	40	30	35.5	0.2	M
19	0	60	0	0	60	2,115	2,100	0	60	0	0				*y*	*y*	46	0.9	P
20	*y*	2*xx*	*y*	5*xx*	7*xx*	1,050 1,250	980 1,230	0	2*xx*	1*x*	0	325	*y*	*y*	38	24	36	*y*	P
21	11	13	0	*y*	*y*	331 1,335	315 1,317	0	13	0	0	*y*	*y*	*y*	36	32	34	0.3	M
22	*y*	22	0	9	31	492 728 758 827 1,193	486 714 747 805 1,168	0	22	0	0	200	200	175	*y*	*y*	38	0.3	M, P, A
23	*y*	227	0	3	230	950 1,250	945 1,244	0	227	0	0	*y*	*y*	*y*	35	30	33	0.2	M, P
24	17	0	0	0	0	850	800	0	0	0	0	250	*y*	*y*					
25	*y*	61	0	0	61	911	899	0	61	0	0				31	27	29	*y*	A
26	*y*	27	0	0	27	1,169	1,161	0	27	0	0				*y*	*y*	*y*	*y*	M
27	*y*	30	0	0	30	920	890	0	5	0	A25				36	35	35.5	0.3	M
28	*y*	1,332		9*xx*	2,25*x*			2	106*x*	1*x*	2*xx*								

the most important discovery in Indiana in 1937. These were the first wells in the state to be drilled with rotary tools. The Prairie Creek field is expected to be developed during the coming year, and should prove to be a good oil area.

An interesting development was the drilling of a new well in the abandoned Riley pool, Vigo County. This well promises to produce

TABLE 1.—(*Continued*)

Line Number	Character of Gas, Approx. Average during 1937	Production Rock						Number of Dry and/or Near-dry Holes to End of 1937	Deepest Zone Tested to End of 1937		Reference to Text[j]
	B.t.u. per Cu. Ft.	Name	Age[f]	Character[g]	Porosity[h]	Net Thickness, Average in Feet	Structure[i]		Name	Depth of Hole, Ft.	
1	940	Oakland City, Brown	MisU	S	Por	*x*	A	34	St. Louis (Mis)	1,413	
2		Mansfield	PenL	S	25	30	ML	9	Chester (MisU)	1,920	
3		Tar Springs, Cypress, Elwren	MisU	S	Por	20	ML	28	Mississippi lime	710	
4		Lower Chester	MisU	S	Por	*y*	A	2*x*	Chester (MisU)	895	
5	950	Brown sand (Paoli)	MisU	S	20	25	A	10	Ordovician	4,006	
6	847	Trenton	Ord	D, L	Por Fis	*y*	A	*y*	Pre-Cambrian	3,055	
7	935	Oakland City (Mooretown)	MisU	S	Por	*y*	A	15	St. Genevieve (Mis)	1,021	
8	950	New Albany	DevU	H	Fis	85	M	39	Trenton (Ord)	1,770	W
9	925	Barker sand	MisU	S	Por	10	T	*y*	St. Genevieve (Mis)	1,021	
10	1,000	Chester sands	MisU	S	Por	15	A	35	St. Louis (Mis)	783	O
11		Mansfield, Cypress, Mooretown, Paoli	PenL MisU	S, L	Por	*y*	M	10	St. Genevieve (Mis)	1,565	
12		Oakland City, Brown sand	MisU	S	Por	*y*	A	44	Paoli (MisU)	1,444	
13	975	Staunton (Unnamed)	PenL	S	Por	*y*	ML	30	Chester (MisU)	1,593	W
14		Sample, Cypress, Mooretown, Paoli	MisU	S	Por	*y*	A	49	Harrodsburg (Mis)	2,050	
15		Corniferous, Niagara	DevM SilM	L	Por	*y*	D	0	Niagara (Sil)	2,190	C
16		Corniferous	DevM	L	Por	*y*	A	13	Corniferous	1,709	O
17		Bethel (Sample)	MisU	S	Por	*y*	MC	9	Mississippi lime	1,500	
18	970	Unnamed (1, 2, 3, 4) Cypress Niagara	PenL MisU Sil	S S L	Por	*y*	AM	67*x*	Niagara (Sil)	2,328	O
19		Corniferous Niagara	DevM SilM	L	Por	*y*	D	16	Trenton (Ord)	3,554	C
20	950	Trenton	Ord.	D, L	Por	*y*	A	3,8*xx*	Pre-Cambrian	3,996	C
21	*y*	Brazil Oakland City	PenL MisU	S	Fis Por	*y*	A	*y*	Paoli (MisU)	1,700	
22	900	Sample, Cypress, Mooretown	MisU	S	Por	*y*	N, MF	39	Mississippi lime	1,708	
23	950	Cypress, Mooretown, Paoli	MisU	S	Por	*y*	A	78	Salem (Mis)	2,205	O
24	980	Corniferous	Dev	D	Por	40	AF	4	Trenton (Ord)	2,102	
25		Mansfield	PenL	S	Por	*y*	ML	26	Glen Dean (MisU)	1,795	
26		Veale sand	MisU	S	Por	*y*	A	54	Devonian (?)	2,618	
27		West Princeton sand (Brazil)	PenL	S	Por	*y*	Af	26	St. Louis (Mis)	2,048	O
28								5,*xxx*			

enough oil to warrant the reopening of the old field. A well drilled in the city limits of Lawrenceburg, Dearborn County, proved the existence of a new gas structure in the Trenton limestone, and the shallow production will probably result in the development of that area in the near future.

Repressuring projects are now in operation in two of the older shallow pools in southwestern Indiana. The West Princeton oil field has been repressured for the past year by the injection of compressed air but very little change was shown in the annual production. The Dodds Bridge pool, in Sullivan County, is being repressured with natural gas, and production seems to have increased to some extent as a result of this treatment.

Acidization of limestone pay horizons became increasingly popular during 1937, especially in the northern portion of the southwestern fields, where production is obtained from Devonian and Silurian limestones. In many wells recently completed, the pay horizons were given a light shot with nitroglycerin and were then acidized. Acidization, however, has been relatively unsuccessful in wells producing from Trenton limestone.

During 1937 many thousands of acres in 15 counties in southwestern Indiana were explored by seismic and other geophysical methods, and leasing began on a large scale. Test wells in these new areas have been

TABLE 2.—*Summary of Drilling Operations in Indiana*

Important Wildcats Drilled in 1937

	County	Location			Total Depth, Feet or Meters	Surface Formation
		Sec.	Twp.	Rge.		
		Survey	Lat.	Long.		
1	Daviess	8	2N	6W	1022	Pen
2	Decatur	18	8N	9E	896	Sil
3	Dubois	36	2S	5W	1202	Pen
4	Gibson	10	4S	11W	1350	Pen
5	Gibson	30	1S	9W	1714	Pen
6	Greene	23	8N	6W	1695	Pen
7	Knox	21	5N	10W	849	Pen
8	Martin	17	4N	3W	450	Pen
9	Martin	12	2N	5W	940	Pen
10	Perry	18	6S	3W	575	Pen
11	Pike	Loc. 17	1N	8W	1011	Pen
12	Pike	24	1N	7W	765	Pen
13	Pike	10	1S	8W	1313	Pen
14	Pike	23	1N	7W	700	Pen
15	Posey	13	6S	13W	1304	Pen
16	Spencer	13	6S	6W	1317	Pen
17	Spencer	1	6S	4W	420	Pen
18	Vanderburgh	18	6S	11W	1318	Pen
19	Vanderburgh	25	4S	11W	1005	Pen
20	Vigo	26	10N	9W	1420	Pen
21	Vigo	33	10N	8W	1900	Pen
22	Vigo	7	11N	9W	2126	Pen
23	Vigo	16	10N	10W	2190	Pen
24	Warrick	12	6S	8W	1530	Pen
	Total					

few, but it is expected that many of the lease blocks will be tested during the spring and summer of 1938.

TABLE 2.—*(Continued)*

Important Wildcats Drilled in 1937

	Deepest Horizon Tested	Drilled by	Initial Production per Day		Pressure, Lb. per Sq. In.	Remarks
			Oil, U. S. Bbl.	Gas, Millions Cu. Ft.	Tubing	
1	Chester	Midwest Dev. Corp.				Dry hole
2	Trenton (L. Ord)	T. E. Castor		0.150	270	
3	M. Mis	A. D. Shaffer				Show gas 372 ft. Show oil 1065 ft.
4	L. Pen	V. C. Besing				Dry hole
5	M. Mis	Big Four Oil & Gas Co.				Show oil 1595 ft.
6	Niagara	Worthington Petr. Corp.				Dry hole
7	L. Pen	W. Hastings et al.				Dry hole
8	Chester	Indian Springs Oil Corp.				Dry hole
9	M. Mis	G. C. Curtis et al.				Dry hole
10	Chester	A. J. Tyler				Show oil 560 ft.
11	Chester	Murphy Oil Co. of Pa.	15			Ruined by shot
12	Chester	John T. Reinsel				Dry hole
13	Chester	H. M. Nedeau, Trustee				Dry hole
14	Chester	A. E. Davis				Dry hole
15	L. Pen	Evans Oil & Gas Co.				Show oil 364 ft.
16	M. Mis	Hollingsworth Gas & Oil Co.				Dry hole
17	Chester	Allen Cotton				Dry hole
18	L. Pen	J. S. Young, Jr.				Dry hole
19	L. Pen	Jas. B. Moffett				Dry hole
20	M. Mis	Hoffmeister & Ring				Show gas 297, 338 and 400 ft.
21	Niagara	Keller Dev. Co.				Show gas 1885
22	Niagara	Pierson & Yaw				Dry hole
23	Niagara	Carter Oil Co.	85			First rotary hole in Indiana
24	Chester	Imperial Oil & Gas Prod. Co.	100	0.150		Show oil 884 and 960 ft.

	In Proven Fields	Wildcats
Number of wells drilling Dec. 31, 1937	28	14
Number of oil wells completed during 1937	38	1
Number of gas wells completed during 1937	36	3
Number of dry holes completed during 1937	24	32

Kansas Oil and Gas during 1937

By W. A. Ver Wiebe* and E. G. Dahlgren,† Junior Member A.I.M.E.

(New York Meeting, February, 1938)

The year 1937 must be considered the most eventful one ever experienced in the development of oil and gas activity. Out of a total of 57 new pools discovered, 18 are apportioned to eastern Kansas and 39 to western Kansas. (For statistical purposes Kansas is divided along the meridian that separates ranges 3 E. and 4 E.) In addition to numerous long-distance extensions of the large Hugoton gas field of southwestern Kansas, two other gas pools were discovered in the area lying west of range 3 E. The 37 new oil pools in that area are to be found in 13 different counties, among which Rice heads the list with a total of seven oil pools and one gas pool. Ellis and Barton Counties both added six new oil pools, while Russell County follows in fourth place with four. Among eastern counties Butler heads the list with four new pools. Cowley and Chautauqua each accounted for three new discoveries.

The number of wells necessary to accomplish this result totals 2657, of which 1915 are oil wells and 128 gas wells. The initial production of the oil wells amounted to 2½ million barrels. Although most of the wells were drilled in proven territory, there was a good deal of wildcatting. The fact that 614 dry holes were completed emphasizes the ever-present risk attendant upon the efforts of pioneers. Some of the more venturesome spirits reached out to the counties farthest west in the state.

An indication of the feverish excitement reached at times is recorded in the fact that no less than 600 drilling operations were in progress during one week in May, or the fact that over 100 new locations were staked during the second week in July. During one week in May, 65 successful oil wells were completed for an initial production of 68,000 barrels.

Many drilling obligations came due during the year, and this perhaps accounts for the fact that one company had as many as 59 active operations at one time during September. Another evidence of great interest in oil possibilities in Kansas is furnished by the record of sales of oil properties, which in one case reached the high figure of about $3000 per acre.

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TABLE 1.—*Oil and Gas Production in Kansas*

Line Number	Field, Survey, Township, Range	Age, to End of 1937		Area Proved, Acres				Total Oil Production, Bbl.	
		Years	Months	Oil	Oil and Gas[a]	Gas	Total	To End of 1937	During 1936
1	*Barber County*							117,812	23,793
2	Aetna, 13-34-15 W					40	40		
3	Lake City, 7-31-13 W		6	40			40	8,292	
4	Medicine Lodge 13-33-13 W 15-33-13 W	11	11 9	 40		6,000	6,000 40	6,708	
5	Whelan, 32-31-11 W	3	5	320			320	102,812	23,793
6	*Barton County*							17,386,331	1,163,590
7	Ainsworth, 26-16-13 W	1	1	1,800			1,800	221,635	
8	Ainsworth South, 10-17-13 W		3	40			40	2,951	
9	Albert 36-18-16 30-18-15 W	2 2	6 9	 1,200		5,000	5,000 1,200	125,157	38,704
10	Beaver, 16-16-12 W	3	1	1,000			1,000	388,369	124,179
11	Beaver North, 4-16-12 W		2	40			40	2,498	
12	Bloomer, 36-17-11 W	1	11	2,000			2,000	1,769,720	295,000
13	Davidson, 4-16-11 W	8	10	40			40	17,437	2,679
14	Eberhardt, 14-19-11 W	2	7	160			160	85,136	44,200
15	Ellinwood, North		6	40			40	8,087	
16	Ellinwood	5	6	1,200			1,200	1,199,622	242,000
17	Feist, 29-18-11 W	2	3	40			40	29,359	18,200
18	Heizer, 16-19-14 W	2	5	40			40	7,458	4,582
19	Hiss, 31-20-13 W	1	8	160			160	139,158	29,000
20	Kraft, 10-17-11 W		7	1,200			1,200	75,486	
21	Lanterman 15-19-11 W	3	3	200			200	64,511	13,500
22									
23	Rick, 1-19-11 W	1	5	160			160	97,429	23,700
24	Silica, 12-20-11 W	5	11	6,100				12,114,096	3,756,446
25	Silica South, 24-20-11 W	2	3	1,800			1,800	917,922	134,500
26	Trapp South, 16-16-13 W	1	1	1,200			1,200	120,300	
27	Trapp Southwest, 1-16-14 W		3	40			40	None	
	Butler County:								
28	Anderson, 7-27-4 E	7	7						
29	Augusta, North, 15-27-4E	23		1,280			1,280	12,899,903	153,707
30	Augusta, South, 21-28-4 E	21		7,660			7,660	32,586,216	424,968
31	Bausinger, 24-27-3 E	7		160			160		
32	Benton, 10-26-3 E	12		40			40		6,000
33	Blankenship, 2-26-8 E	16		1,200			1,200		
34	Brandt, 15-28-7 E	1	7	40			40	8,867	2,730
35	De Moss, 5-28-7 E	3	3	160			160	14,384	7,200
36	Douglas 2-29-4 E 13-29-3 E	21		2,400			2,400		39,600
37	Elbing, 8-23-4 E	19	5	1,800			1,800	17,463,492	396,000
38	El Dorado, 29-25-5 E	22		25,020			25,020	162,396,429	3,492,325
39	Fox Bush, 25-28-5 E	20		5,000			5,000	15,166,330	192,000
40	Garden-Shaffer 32-26-6 E 17-27-6 E	11		1,600			1,600		252,000
41	Gelwich, 6-27-4 E								
42	Haverhill, 27-27-5 E	10	9	700			700	2,856,765	120,863
43	Hazlett, 1-24-4 E	16		40			40		2,400

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[a] Footnotes to column heads and explanation of symbols are given on page 313.

Table 1.—(*Continued*)

Line Number	Total Oil Production, Bbl.		Total Gas Production, Millions Cu. Ft.				Number of Oil and/or Gas Wells								Depth, Average in Feet	
	During 1937	Daily Average during Nov. 1937	To End of 1937	During 1936	During 1937	Maximum Daily during 1937	Completed to End of 1937	During 1937		At End of 1937					Bottoms of Productive Wells	To Top of Productive Zone
								Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Oil and Gas[b]	Producing Gas Only	Total Producing		
1	73,020										7		21			
2			y	y	y	y							1	1	5,260	5,215
3	8,292						1	1			1			1	4,440	4,435
4			29,000			6					1		20	20	4,465	4,455
	6,708						1	1						1	4,847	4,845
5	58,020						6				5			5	4,384	4,355
6	10,623,956						580									
7	221,635						39				34			34	3,395	3,390
8	2,951										2			2	3,352	3,342
9			y	y	y	y							8	18	3,636	3,537
	76,740						15				10				3,606	3,603
10	251,190						17				14			14	3,351	3,348
															3,341	3,335
11	2,498						1				1			1	3,326	3,316
							1				1			1		
12	1,414,720						81				79			79	3,281	3,257
							y				1			1		
13	12,758						1				1			1	3,340	3,314
14	40,277						4				4			4	3,360	3,311
15	8,087						2				2			2	3,350	3,328
16	207,522						21				16			16	3,334	3,304
17	11,159						1				1			1	3,433	3,430
18	None						1				1			1	3,253	3,228
19	110,158						7				4			4	3,285	3,270
20	75,486						16				16			16	3,289	3,281
21	41,023						7				4			4	3,115	3,040
22											2			2	3,235	3,232
23	73,729						8				5			5	3,355	3,353
24	7,252,983						424				405			405	3,328	3,309
25	873,711										62			62	3,284	3,274
26	120,300										18			18	3,372	3,357
27											1			1	3,366	3,341
28															2,924	
															2,035	1,900
29	146,503						280				69			69	2,410	2,380
															2,460	2,410
30	393,378						740				165			165	2,520	2,445
															2,600	
31	16,075										3			3	3,079	3,050
32	6,036										2			2		2,765
33	91,957										95			95	2,700	2,650
34	6,137										1			1		2,700
35											3			3		2,700
36	27,604										24			24	1,830	1,790
37	463,492										90			90	2,400	2,330
															2,470	2,430
38	3,340,426												15			600
																1,700
											1,789			1,804		2,500
																2,510
																2,550
39	166,330										177			177	2,770	2,730
40	217,065										61			61	2,770	2,760
																3,200
41											2			2		
42	112,784										66			66	2,750	2,700
43	1,122										4			4	2,490	2,470

TABLE 1.—(*Continued*)

Line Number	Pressure, Lb. per Sq. In.[d]			Character of Oil, Approx. Average during 1937	Character of Gas, Approx. Average during 1937		Producing Rock						Number of Dry and/or Near-dry Holes to End of 1937	Deepest Zone Tested to End of 1937	
		Average at End of		Gravity A.P.I. at 60° F.											
	Initial	1936	1937	Weighted Average	B.t.u. per Cu. Ft.	Gal. Gasoline per M Cu. Ft.	Name	Age[f]	Character[g]	Porosity[h]	Net Thickness, Average in Feet	Structure[i]		Name	Depth of Hole, Ft.
1													33		
2	y				y	y	Viola	Ord	L		45		0	Arbuckle	
3							Viola	Ord	L		5		0		
4	1,625						Chat Viola	Mis Ord	IR L		10 2	D	4 0	Pre-Cam	
5				27			Chat	Mis	IR		29	A	1	Arbuckle	4,975
6													157		
7							Arbuckle	Ord	D		5	A	5		
8				38			Arbuckle	Ord	D		10		0		
9							Reagan Reagan	Cam Cam	S S		59 3	A	5	Pre-Cam	
10				38			Arbuckle Reagan	Ord Cam	D S		3 6	A	3	Pre-Cam	
11				39			Arbuckle	Ord	D		10		0		
12				44			Lans.-K. C. Arbuckle	Ord	D		24	A	2	Reagan	3,491
13				38			Conglomerate Arbuckle	Pen Ord	DR D		26	A	1	Pre-Cam	
14				38			Arbuckle	Ord	D		49		0		
15							Arbuckle	Ord	D		22		0		
16				41			Arbuckle	Ord	D		30	Af	5	Reagan	3,593
17				39			Arbuckle	Ord	D		3		0		
18				48			Lans. K. C.	Pen	L		25	A		Pre-Cam	
19				36			Lans. K. C.	Pen	L		15	A	3	Arbuckle	3,650
20							Arbuckle	Ord	D		8		0		
21				42			Lansing Kans. C.	Pen	L		75		1		
22				38			Arbuckle	Ord	D		3				3,397
23				36			Arbuckle	Ord	D		2		3		3,425
24				42			Arbuckle	Ord	D		19	A	17	Pre-Cam	3,796
25				42			Arbuckle	Ord	D		10	D		Pre-Cam	
26							Arbuckle	Ord	D		15	A			
27							Arbuckle	Ord	D		25				
28				26			Viola	Ord	L						
29				33			Kansas City Wilcox Arbuckle	Pen Ord Ord	L S D		135 30 50	A		Pre-Cam	
30							Wilcox Arbuckle	Pen Ord	L L, D		75 5	A		Pre-Cam	
31							Wilcox	Ord	S		29	A		Arbuckle	
32				40			Chat	Mis	IR			MC		Ord	
33							Bartlesville	Pen	S			ML		Mis	
34							Chat	Mis	IR			MC			
35							Bartlesville	Pen	S			ML		Mis	
36							Lans. K. C. Viola	Pen Ord	L L		40	A		Arbuckle	
37				32			Lans. K. C. Viola	Pen Ord	L L		70 40	D		Arbuckle	
38				36 35			Admire Lans. K. C. Viola Simpson Arbuckle	Pen Pen Ord Ord Ord	S L L S D		15	A		Pre-Cam	
39							Bartlesville	Pen	S		40	ML		Mis	
40							Bartlesville Viola	Pen Ord	S L			MC		Arbuckle	
41															
42				39			Bartlesville	Pen	S		50	ML		Wilcox	
43							Chat	Mis	IR		20	MC		Pre-Cam	

TABLE 1.—*(Continued)*

Line Number	Field, Survey, Township, Range	Age, to End of 1937		Area Proved, Acres				Total Oil Production, Bbl	
		Years	Months	Oil	Oil and Gas[a]	Gas	Total	To End of 1937	During 1936
44	Keighley, 27-27-7 E.	12		1,600			1,600		
45	King, 17-24-4 E.		11	80			80	1,999	
46	Kramer, 4-28-6 E.	11		500			500		189,000
47	Leon, 19-27-6 E.	11	3	500			500		24,000
48	McCullough, 1-28-6 E.	1	11	300			300	103,255	
49	McKaig, 13-28-6 E.		10	80			80	6,000	
50	Madden, 27-23-4 E.		8	40			40	70	
51	Moore, 12-25-3 E.			100			100		
52	Pettit, 21-28-6 E.	2	6				40		
53	Potwin, 36-24-3 E.	16		3,000			3,000		444,000
54	Seward, 14-27-7 E.			600			600		
55	Smock-Sluss { 19-26-6 E.	19	10	1,500			1,500		68,400
	{ 2-27-5 E.								
56	Steinhoff, 21-29-6 E.	11		40			40		10,800
57	Stern, 27-27-6E.	9		600			600		
58	Weaver, 1-28-5 E.	7		160			160		
59	Young, 27-26-7 E.	17		400			400		
	Chautauqua County:								
60	Fisher, 10-34-9 E.	1							
61	Foster, 6-33-12 E.		6	40			40		
62	Kingston, 17-32-10 E.			40			40		
	Clark County:								
63	Morrison { 21-32-21 W.	9	2			600	600 }		
	{ 17-32-21 W.	1	3	600			600 }	31,226	2,300
	Coffey County:								
64	Van Noy, 18-23-15 E.			150			150		
	Cowley County:								
65	Baird, 20-34-3 E.			160			160		
66	Biddle, 12-32-4 E.								
67	Burden, 22-31-6 E.	11		1,200			1,200		186,000
68	Carson, 19-32-3 E.	13	7	400			400	2,773,691	87,600
69	Clarke, 6-31-4 E.	23		180			180	782,603	9,600
70	Countryman, 4-33-7 E.								
71	David, 35-30-4 E.	2	8	500			500		101,000
72	David South, 11-31-4 E.	3		160			160		
73	Dexter-Otto, T. 33 + 34 S., R. 6 + 7 E.	34			1,000		1,000		
74	Eastman, 31-30-6 E.	13			700		700	2,167,123	86,400
75	Falls City, 17-35-7 E	21		400			400	789,230	
76	Ferguson West, 21-30-8 E.			100			100		
77	Frog Hollow, 20-32-5 E.	1		160			160	33,435	
78	Geuda Springs, 8-34-3 E.	1	8	80			80	70,472	
79	Graham, 12-33-3 E.	13	7		400		400	2,383,915	43,960
80	Grand Summit, 4-31- 8 E.								
81	Hittle, 21-31-4 E.	11		400			400		26,154
82	Murphy, 8-35-3 E.	4							65,719
83	Olsen, 1-35-7 E.			160			160		
84	Rainbow Bend, 20-33-3 E.	14	1		2,000		2,000	11,870,055	350,712
85	Rainbow Bend West, 24-33-2 E.	11	9	160			160		
86	Reidy, 31-31-8 E.			80			80		
87	Rock, 14-30-4 E.	14		200			200	1,199,835	23,904
88	Rock West, 16-30-4 E.		3	80			80	5,464	

TABLE 1.—(*Continued*)

Line Number	Total Oil Production, Bbl.		Total Gas Production, Millions Cu. Ft.				Number of Oil and/or Gas Wells								Depth, Average in Feet	
								During 1937		At End of 1937						
	During 1937	Daily Average during Nov. 1937	To End of 1937	During 1936	During 1937	Maximum Daily during 1937	Completed to End of 1937	Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Oil and Gas[b]	Producing Gas Only	Total Producing	Bottoms of Productive Wells	To Top of Productive Zone
44	93,150										47			47	2,700	2,650
45	1,999										2			2	2,265	2,145
46	78,111										22			22	3,150	
47	37,825										26			26	2,710	2,660- 3,050
48						184					7			7	3,175	3,169
49	6,000										2			2	2,740	2,720
50	70										1			1	2,212	2,065
51	16,601										3			3		
52											1			1	3,163	3,160
53	414,980										75			75	2,255 2,755	2,250 2,660
54	26,953					135					21			21	2,700	2,650
55	67,437					178					46			46	2,715	2,685 3,000
56	7,120					20					2			2		2,700
57	84,072										11			11		3,150
58						16					10			10		2,690
59	37,568										17			17	2,700	2,650
60											1			1	1,679	1,648
61							1				1			1	2,230	2,200
62															1,439	1,437
63	28,926		*y*	*y*	*y*	*y*	8 1 5				3		1	1 3	5,475 6,481	5,443 6,467
64	47,052	109									37			37	1,150 1,628	1,138 1,622
65	7,931	134					12		4		4			4		
66	36,901						40		1		22			22		
67	130,320						54		4		36			36		
68	67,691	184					24				20			20		2,600 3,450
69	10,603	25					10				3			3		2,840
70	27,583						15		1		9			9		
71	76,964	200									11			11	2,975	2,935
72	23,591										4			4	3,029	3,010
73	4,538		*y*	*y*	*y*	*y*	40		15		3			3		325 1,100 2,750
74	83,123	218							3		34			34	2,870	2,770
75	18,730	44	15,000				30		9		13			13		2,000
76	8,498										3			3		
77	33,435										4			4	3,097	3,089
78	54,298	196									9			9		3,320
79	38,915						37		14		15			15		2,500 3,500
80	48,357										13			13		
81	26,402	70					22		4		13			13		2,400
82	44,158										12			12		
83							9				8			8		
84		1,200					126		1		113			113	3,250	3,200
85	6,755						17		9		3			3	3,250	3,200
86											3			3		
87	25,931	64					29		2		19			19	2,805	2,760
88	5,464										2			2	2,802	2,784

TABLE 1.—(*Continued*)

Line Number	Pressure, Lb. per Sq. In.[d]			Character of Oil, Approx. Average during 1937	Character of Gas, Approx. Average during 1937		Producing Rock						Number of Dry and/or Near-dry Holes to End of 1937	Deepest Zone Tested to End of 1937	
	Initial	Average at End of 1936	Average at End of 1937	Gravity A.P.I. at 60° F. Weighted Average	B.t.u. per Cu. Ft.	Gal. Gasoline per M Cu. Ft.	Name	Age[f]	Character[g]	Porosity[h]	Net Thickness, Average in Feet	Structure[i]		Name	Depth of Hole, Ft.
44				39			Bartlesville	Pen	S		50	ML		Mis	
45							Kansas City	Pen			120				
46				36			Viola	Ord	L		}	MC		Arbuckle	
47				38			{ Chat	Mis	IR		50 }	A		Arbuckle	
							{ Viola	Ord	L						
48							Wilcox	Ord	S		13	A			
49							Bartlesville	Pen	S		20	ML			
50							Lans-K. C.	Pen	L		47				
51															
52							Arbuckle	Ord	D		3	MC			
53							{ Lans. K. C.	Pen	L		5	MC		Arbuckle	
							{ Chat	Mis	IR		65	MC			
54							Bartlesville	Pen	S				4		
55				39			{ Bartlesville	Pen	S		35	ML			
							{ Viola	Ord	L			MC			
56							Chat	Mis	L			MC			
57							Viola								
58							Bartlesville	Pen	S			ML		Mis	
59							Chat	Mis	IR		50	D		Mis	
60							Altamont				31				
61							Mississippi lime	Mis	L		30				
62							Lans. K. C.								
63	y				y	y	{ Basal conglomerate	Pen	S		6			{ Arbuckle	
							{ Viola	Ord	L		14		2	{ Arbuckle	6,906
64							{ Peru	Pen	S		12	ML			
							{ Chat	Mis	IR		6	MC			
65															
66													4		
67													17		
							{ Peru	Pen	S			ML	14	Arbuckle	
							{ Bartlesville	Pen	S			ML		Arbuckle	
68				38			{ Layton	Pen	S			D	4	Arbuckle	
				40			{ Arbuckle	Ord	D						
69				38											
70							Bartlesville	Pen	S			ML	7	Ordovician	
71															
72							Bartlesville	Pen	S			ML	5	Mis	
							Bartlesville	Pen	S						
73	250						{ Admire	Pen	S			A			
							{ Shawnee	Pen	S						
74				34			Mississippi lime	Mis	IR			A	22	Pre-Cam	
75				41			Bartlesville	Pen	S		100	ML	17	Ordovician	
76							Stalnaker	Pen	S			N	7	Ordovician	
77							Bartlesville	Pen	S		8				
78							Chat	Mis	L			D			
79				{ 38			{ Layton	Pen	S			D		Mis	
				{ 40			{ Arbuckle	Ord	D						
80													8		
81															
82							Stalnaker	Pen	S			MC	5	Arbuckle	
83							Chat	Mis	IR						
84				40									1		
85							Burgess	Pen	S		50	ML	12	Ordovician	
86							Burgess	Pen	S				5		
87				38									2		
88							Bartlesville	Pen	S		45	ML	8	Ordovician	
							Bartlesville	Pen	S			18	ML		

TABLE 1.—(*Continued*)

Line Number	Field, Survey, Township, Range	Age, to End of 1937		Area Proved, Acres				Total Oil Production, Bbl.	
		Years	Months	Oil	Oil and Gas[a]	Gas	Total	To End of 1937	During 1936
89	Rock North, 3-30-4 E.		4	80			80	3,564	
90	Sherwood, 11-31-4 E.	1	8	40			40		10,882
91	Smith, 10-31-3 E.	20		200			200		19,429
92	State, 15-32-4 E.	11		1,500			1,500		31,508
93	Trees, 19-30-4 E.	3							89,790
94	Turner, 30-32-6 E.		7					21,314	
95	Wethered 4-32-3 E. 28-31-3 E.	2	6						147,777
96	Winfield, 13 to 36 of 32-4 E.	23	2		5,000		5,000		346,580
	Edwards County:								
97	McCarty, 30-25-17 W.	8	8		80		80	98,690	2,306
	Elk County:								
98	Denton, 29-30-9 E.	26			3,600		3,600		
99	Ferguson, 6-31-8 E.	9	6	400			400		72,720
100	Hanna, 12-29-8 E.			600			600		
101	Julian, 35-31-10 E.		5						
102	Moline, 3-31-10 E.	10	1	600			600		
103	Sellars, 11-31-9 E.		6					1,527	
104	Webb, 28-31-10 E.	13	3	3,600			3,600		
		1	5						
105	*Ellis County*							4,525,882	717,476
106	Antonino, 26-14-19 W.	1	7	20			20	9,028	4,862
107	Bemis, 16-11-17 W.	2	3	3,200			3,200	1,887,390	255,525
108	Blue Hill, 14-12-16 W.		5 3	640 640			640 640	7,864	
109	Burnett, 1-11-18 W.		4	40			40	None	
110	Catherine, 3-13-17 W.	1	7	160			160	48,716	10,400
111	Cress, 13-11-17 W.		10	200			200	130,809	
112	Emmeram, 4-13-16 W.		7	40			40	10,683	
113	Hadley, 20-11-17 W.	8	5	40			40	75,000	
114	Haller, 10-11-18 W.	1	6	40			40	8,022	6,734
115	Kobletz, 23-12-18 W.		8	40			40	1,745	
116	Kraus, 22-14-9 W.	1	6	40			40	25,307	6,430
117	Madden 26-15-18 W.	1 1	7 3	160 160			160 160	26,196	5,490
118	Marshall, 36-11-18 W.	1	2	1,000			1,000	123,681	
119	Penny Whan, 13-15-20 W.	1	4	10			10	4,946	
120	Ruder, 17-15-18 W.	2	5	700			700	384,462	210,246
121	Shutts 5-12-17 W. 32-11-17 W.	9	2	2,000			2,000	1,436,170	186,180
122	Solomon, 28-11-19 W.	1	7	160			160	24,261	
123	Toulon, 3-14-17 W.	2	1	160			160	49,171	13,600
124	Ubert, 12-13-18 W.	1	2	80			80	17,950	
125	Victoria, 18-14-16 W.		4	40			40		

TABLE 1.—(*Continued*)

	Total Oil Production, Bbl.		Total Gas Production, Millions Cu. Ft.				Number of Oil and/or Gas Wells								Depth, Average in Feet	
								During 1937		At End of 1937						
Line Number	During 1937	Daily Average during Nov. 1937	To End of 1937	During 1936	During 1937	Maximum Daily during 1937	Completed to End of 1937	Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Oil and Gas[b]	Producing Gas Only	Total Producing	Bottoms of Productive Wells	To Top of Productive Zone
89	3,564										2			2	2,828	2,807
90	11,425										2			2		
91	15,485	43							1		12			12		3,050
92	116,521	304									41			41		2,300 3,500
93	87,027	200									9			9		
94	21,314										6			6	2,247	2,232
95	346,619										1 22			1 22	2,554	2,455 3,400
96	152,985	382	*x* *x* *x*						25		68			68		600 1,400 2,300
97	12,000		5*x*				15				1		2	1	4,553	4,545
98											56			56		1,450 2,200 2,640
99											12			12		1,865 2,912
100											34			34	2,021	2,000
101											1			1		2,040
102											42		10	52		1,150
103	1,527										1			1	2,322	1,980 2,300
104											127		20	147		1,100 1,350 1,650 2,286
105	2,694,663															
106							3				Abandoned				3,710	3,703
107	1,630,740						151				148			148	3,040 3,382	3,032 3,380
108	7,864										1			1	3,105	3,072
109	None										1			1	3,385	3,360
110	38,316										1			1	3,574	3,570
111	130,809										4			4	3,362	3,274
112	10,683										18			18	3,302	3,293
113	None										1			1	3,267	3,260
114	1,288										1			1	3,440	3,428
115	1,745						2				1			1	3,045	3,036
116	18,977										1			1	3,698	3,694
117	20,706										2			2	3,740	3,735
											1			1	3,341	3,331
118	123,681						2				1			1	3,595	3,589
117	4,946						14				12			12		3,650
120	170,576						2				1			1	3,658	3,653
							19				17			17	3,440 3,582	3,422 3,572
121	243,309						25		2		16			16	3,284 3,575	3,280 3,569
122	24,261						5				3			3	3,632	3,629
123	35,255										2			2	3,303	3,298
124	17,950						2				1			1	3,560	3,512
125											2			2	3,707	
											1			1	3,268	3,225
											1			1	3,464	3,422

TABLE 1.—(*Continued*)

Line Number	Pressure, Lb. per Sq. In.[d]			Character of Oil Approx. Average during 1937	Character of Gas, Approx. Average during 1937		Producing Rock						Number of Dry and/or Near-dry Holes to End of 1937	Deepest Zone Tested to End of 1937	
	Initial	Average at End of 1936	Average at End of 1937	Gravity A.P.I. at 60° F. Weighted Average	B.t.u. per Cu. Ft.	Gal. Gasoline per M Cu. Ft.	Name	Age[f]	Character[g]	Porosity[h]	Net Thickness, Average in Feet	Structure[i]		Name	Depth of Hole, Ft.
89							Bartlesville	Pen			21			Mis	
90							Bartlesville	Pen	S						
91							Bartlesville	Pen	S			N	3	Ordovician	
92							Layton	Pen	S			D		Arbuckle	
							Arbuckle	Ord	D				14		
93							Bartlesville	Pen	D			ML		Mis	
94							Layton	Pen	S		15				
95				35			Lans. K. C.	Pen	L		99				
							Arbuckle	Ord	D			D		Arbuckle	
96				37			Admire	Pen	S						
				34			Peacock	Pen	S						
				34			Layton	Pen	S			A	47		
							Bartlesville	Pen	S						
							Arbuckle	Ord	D					Reagan	4,140
97				35			Basal conglomerate	Pen	DR		8		8	Arbuckle	
98							Encill	Pen	S			D		Arbuckle	
							Mississippi lime	Mis	L						
							Arbuckle	Ord							
99				36			Encill	Pen	S			AM		Arbuckle	
							Layton	Pen	S						
							Arbuckle	Ord	D						
100							Chat	Mis	L		21			Arbuckle	
101							Mississippi lime	Mis	L						
102				36			Encill	Pen	S			N			
							Mississippi lime	Mis	L						
103							Mississippi lime	Mis			22				
104				37			Encill	Pen	S			D		Arbuckle	
							Red	Pen	S						
							Ft. Scott	Pen	L						
							Arbuckle	Ord	D						
105													115		
106				32			Basal conglomerate	Pen	S		7	D	2	Arbuckle	3,823
107				29			Topeka	Pen	L		8	D	3	Pre-Cam	
				33			Arbuckle	Ord	D		2				
108							Lans. K. C.	Pen			33				
							Arbuckle	Ord	D		25				3,809
109				32			Arbuckle	Ord			4				
110				30			Lans. K. C.	Pen			88			Arbuckle	
111				35			Arbuckle	Ord			9				
112							Lans. K. C.	Pen			7				
113				29			Conglomerate	Pen	DR		12				
114				40			Topeka	Pen	L		9		1	Arbuckle	3,501
115							Arbuckle	Ord			4				
116				35			Conglomerate	Pen	DR		5				
117				37			Lans. K. C.	Pen	L		81			Arbuckle	
							Arbuckle	Ord	D		6		1		
118							Arbuckle	Ord	D				2		
119				31			Conglomerate	Pen	DR		5		1	Pre-Cam	
120				42			Lans. K. C.	Pen	L		197	D		Arbuckle	3,759
				36			Arbuckle	Ord	D		10		2		
121				35			Lans. K. C.	Pen	L		4			Arbuckle	3,923
				29			Arbuckle	Ord	D		6		7		
122				21			Arbuckle	Ord	D		3		2		
123				36			Lans. K. C.	Pen	L		5				
				33			Arbuckle	Ord	D		48		1		
124							Arbuckle	Ord	D						3,626
125							Lans. K. C.	Pen	L		43				
							Arbuckle	Ord	D		42				

TABLE 1.—(*Continued*)

Line Number	Field, Survey, Township, Range	Age, to End of 1937		Area Proved, Acres				Total Oil Production, Bbl.	
		Years	Months	Oil	Oil and Gas[a]	Gas	Total	To End of 1937	During 1936
126	Walters, 2-12-18 W.	1	8	700			700	193,590	18,000
127	Yocemento, 9-13-19 W.	8	7	40			40	60,891	None
128	*Ellsworth County*							10,850,957	
129	Breford, 7-17-10 W.	5 1	4	700			700	661,464	128,284
130	Heiken, 25-17-10 W.	7	3	320			320	285,713	41,384
131	Lorraine, 13-17-9 W.	3	2	5,500			5,500	5,872,069	2,430,105
132	Stoltenberg, 21-16-10 W.	6	6	600			600	2,058,180	213,579
133	Stratman, 12-17-10 W.	6	9	600			600	1,847,867	158,024
134	Wilkins, 13-17-10 W.	3	9	80			80	125,664	
135	*Greenwood County*								3,700,000
136	Atyeo-Pixlee, 25-21-10 E.	14		1,000			1,000		110,727
137	Brinegar, 32-26-13 E.			500			500		
138	Browning, 20-22-10 E.	13		3,800			3,800		257,020
139	Burkett, 13-23-10 E.	13		2,700			2,700		83,632
140	Christy, 36-24-12 E.			160			160		
141	Climax, 4-27-11 E.	11		160			160		6,204
142	DeMalorie-Souder { 19-21-10 E 6-22-10 E }	13		4,500			4,500		186,100
143	Dunaway, 4 to 34- 22 S.-13 E.			1,000			1,000		
144	Eureka, 35-25-10 E.	17		1,200			1,200		20,200
145	Fankhauser { 32-21-12 E 10-22-12 E }	11		2,500			2,500		53,100
146	Hamilton { 26-23-11 E 6-24-12 E }	8		3,000			3,000		162,650
147	Henley, 25-25-9 E.		2	40			40		
148	Hinchman, 17-24-13 E.			200			200		
149	Lamont { 5-22-12 E 28-22-13 E }	10		2,600			2,600		170,400
150	Madison, 1 to 15 of 22-11 E.	16		3,000			3,000	5,500,000	284,650
151	Pedroja, 6-26-10 E.	1		40			40		
152	Polhamus { 34-24-9 E 9-25-9 E }	15		1,400			1,400		
153	Quincy { 25-24-12 E 18-25-14 E }	11		3,600			3,600		307,530
154	Reece, 21-26-9 E.			1,200			1,200		45,450
155	Sallyards { 17-25-9 E 26-26-8 E }	16		8,000			8,000		278,000
156	Schwab, 9-24-10 E.								
157	Scott { 19-23-9 E 26-23-8 E }	12		2,500			2,500		91,390
158	Seeley-Wick { 22-22-11 E 27-23-11 E }	15		7,000			7,000		396,000
159	Severy, 16-28-11 E.			200			200		5,400
160	Taylor, 6-27-12 E.		5	40			40		
161	Teeter { 36-22-9 E 28-23-9 E }	15		2,700			2,700		264,000
162	Teichgraber { 13-25-8 E 18-25-9 E }			900			900		
163	Thrall-Agard { 28-23-10 E 9-25-9 E }			7,000			7,000		
164	Virgil { 24-22-13 E 26-24-12 E }	21		18,000			18,000	25,500,000	576,000
165	Wiggins { 7-24-11 E. 36-24-10 E }	12		2,500			2,500		
166	Wilkerson, 6-25-9 E.								60,000
167	Willard, 7-27-11 E.								42,000

TABLE 1.—(*Continued*)

Line Number	Total Oil Production, Bbl.		Total Gas Production, Millions Cu. Ft.				Number of Oil and/or Gas Wells								Depth, Average in Feet	
	During 1937	Daily Average during Nov. 1937	To End of 1937	During 1936	During 1937	Maximum Daily during 1937	Completed to End of 1937	During 1937		At End of 1937					Bottoms of Productive Wells	To Top of Productive Zone
								Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Oil and Gas[b]	Producing Gas Only	Total Producing		
126	175,590						22				19			19	3,165	3,160 3,619
127	None						7		4		1			1	3,597	3,592
128	2,352,957															
129	145,087						18				1 14			1 14	3,180 3,395	3,150 3,368
130	26,400						11		2		5			5	3,271	3,269
131	1,742,069						107		3		2 96			2 96	3,060 3,205	2,953 3,200
132	213,431						20		3		16			16	3,347	3,333
133	147,220						26		2		17			17	3,271	3,255
134							6				4			4	3,280	3,260
135																
136	203,328						130		10		98			98		2,327
137	9,285						40		2		31			31		
138	187,624	532					143		20		105			105	2,390	2,314
139	79,070	210					139		24		102			102	2,100	2,000
140	4,601						16				11			11		1,500
141							6		1		3			3		1,900
142	170,637	470					183		2		130			130		2,150
143	93,593						82		4		61			61		1,800
144	21,498	65									15			15		2,000
145	50,232						94		8		71			71		1,750
146	151,877						129		1		92			92	1,837	1,765
147							1				1			1	2,165	2,140
148	19,814						16				13			13	1,650	1,600
149	141,426						138		5		112			112		1,650
150	229,744	652					131		3		111			111		1,800
151											1			1	2,161	2,154
152	34,573						69		3		51			51		2,170
153	414,703						124				99			99		1,420
154	73,844	223					24		1		19			19		2,100
155	171,865	462					166		16		133			133	2,500	2,350
156											1			1		2,700
157	96,053						89		2		73			73	2,600	2,525
158	308,049	1,074					407		10		330			330	1,975	1,930
159							9		3		2			2		
160							1				1			1	1,897	1,854
161	240,842	687					269		8		208			208	2,550	2,400
162	21,457						25				21			21		2,450
163	199,016	596					283		1		255			255	2,350	2,190
164	126,435	1,200 321					474		10		417			417		1,550 1,700
165	68,573						86		21		48			48	1,875	1,860
166	20,542	45									15			15		2,500
167	11,591						13		5		4			4		

TABLE 1.—(*Continued*)

	Pressure, Lb. per Sq. In.[d]			Character of Oil, Approx. Average during 1937	Character of Gas, Approx. Average during 1937		Producing Rock						Number of Dry and/or Near-dry Holes to End of 1937	Deepest Zone Tested to End of 1937	
		Average at End of		Gravity A.P.I. at 60° F.											
Line Number	Initial	1936	1937	Weighted Average	B.t.u. per Cu. Ft.	Gal. Gasoline per M Cu. Ft.	Name	Age[f]	Character[g]	Porosity[h]	Net Thickness, Average in Feet	Structure[i]		Name	Depth of Hole, Ft.
126				{ 35		{	Topeka	Pen	L		35		3		3,719
				26			Arbuckle	Ord	D						
127				32			Lans. K. C.	Pen			5		2		4,358
128													97		
129						{	Lans. K. C.	Pen	L		30				
				45			Arbuckle	Ord	D		27		4		3,500
130				39			Arbuckle	Ord	D		21	A	4		3,343
131						{	Lans. K. C.	Pen	L		107				
				46			Arbuckle	Ord	D		5	A	8		3,628
132				44			Arbuckle	Ord	D		14	A	1		3,448
133				43			Arbuckle	Ord	D		16	A	7		3,344
134				46			Arbuckle	Ord	D		20		2		3,305
135															
136				41			Bartlesville	Pen	S			ML	22		
137													7		
138				41			Bartlesville	Pen	S		76	ML	18		
139				41			Bartlesville	Pen	S		100	ML	13	Arbuckle	
140							Bartlesville	Pen	S				5		
141				32			Mississippi lime	ML				MC	2		
142				41			Bartlesville	Pen	S			ML	51		
143							Mississippi lime	Mis	L				18		
144							Mississippi lime	Mis	L			MC			
145				41			Bartlesville	Pen	S			ML	15		
146				41			Bartlesville	Pen	S		72	ML	36		
147							Mississippi lime	Mis	L		25				
148							Mississippi lime	Mis	L						
149				41			Bartlesville	Pen	S			ML	11		
150				41			Bartlesville	Pen	S			ML	17		
151							Mississippi lime	Mis	L		7				
152							Bartlesville	Pen	S				14		
153				38			Bartlesville	Pen	S		25	ML	25		
154							Mississippi lime	Mis	Ls			MC	4		
155							Bartlesville	Pen	S		250	ML	17		
156							Arbuckle								
157							Bartlesville	Pen	S		75	ML	14		
158				42			Bartlesville	Pen	S		45	ML	67		
159							Mississippi lime	Mis	L			MC	4		
160							Mississippi lime	Mis			43				
161				41			Bartlesville	Pen	S		150	ML	53		
162							Bartlesville						4		
163							Bartlesville	Pen	S		160	ML	27		
164				41			Bartlesville	Pen	S			ML	47		
							Mississippi lime	Mis	L			ML			
165				40			Bartlesville	Pen	S		15	ML	19		
166				41			Bartlesville	Pen	S			ML	4		
167															

TABLE 1.—(*Continued*)

Line Number	Field, Survey, Township, Range	Age, to End of 1937		Area Proved, Acres				Total Oil Production, Bbl.	
		Years	Months	Oil	Oil and Gas^a	Gas	Total	To End of 1937	During 1936
168	*Harvey County*							17,199,808	1,499,393
169	Halstead, 11-23-2 W	9	5		1,200		1,200	636,656	81,750
170	Hollow-Nikkel 30-22-3 W	6	1	1,500			1,500		
	19-22-3 W								
	20-22-3 W							16,333,585	1,354,600
	20-22-3 W								
171	Sperling 24-22-2 W	3	11	500			500		
	23-22-2 W							94,567	21,502
	23-22-2 W								
	Haskell County								
172	Santa Fe								
173	*Kingman County*							1,472,304	211,527
173*a*	Cunningham, 30-27-10 W	7			1,200		1,200	1,445,304	211,527
174	*McPherson County*							55,537,861	4,383,519
175	Bornholdt, 30-20-5 W		5	40			40	1,647	
176	Canton North, 26-18-1 W	1	6	40			40	24,827	9,784
177	Chindberg, 13-19-3 W	8			700		700	849,349	187,280
				700			700		
178	Graber 17-21-1 W		7		40		40	2,043,081	474,470
	32-21-1 W	3	8	2,400			2,400		
179	Johnson 35-19-3 W	5	11			1,200	1,200		
	2-20-3 W			1,200			1,200	2,100,000	174,000
180	McPherson 29-18-2 W	11	4			2,000			
	31-18-2 W	9	6	2,000			2,000	600,000	160,700
	27-18-2 W	11	4						
181	Ritz-Canton 12-20-2 W	9	1			13,000	13,000		
	11-20-2 W	8	6	13,000			13,000	28,850,360	2,317,100
	30-19-1 W								
	7-20-1 W								
182	Voshell 34-20-3 W	8	5			3,500	3,500		
	9-21-3 W								
	9-21-3 W			3,500				21,068,598	1,100,633
	9-21-3 W								
183	*Marion County*								269,378
184	Covert-Sellers, 21-4 E	17	4	2,400			2,400		67,200
185	Florence Urshell, 20-21-5 E	18	1	3,000			3,000		68,400
186	Hillsboro, 7-19-3 E	10	3	300			300		120,900
187	Lost Springs, 22-17-4 E	11	4	2,400			2,400		12,900
188	Peabody, 5-22-4 E	18	4	3,000			3,000		
189	Propp, 8-19-4 E	11	9						
	Morton County:			See under Southwest Kansas					
190	*Ness County*								7,070
191	Aldrich, 7-18-25 W	8	3	40			40	19,174	7,070
				800			800		
192	*Pawnee County*							9,876	
193	Pawnee Rock, 13-20-16 W	1	4	160			160		
	Pratt County:								
194	Cairo, 7-28-11 W		2			160	160		
195	Iuka, 11-27-13 W		5	40			40	2,921	
196	*Reno County*							23,833,614	6,043,935
197	Abbyville, 24-24-8 W	10	11	1,200			1,200	281,685	51,135
198	Burrton 23-23-4 W	6	9						
	1-23-4 W	6	11	5,000			5,000	21,410,489	5,364,976
	26-23-4 W	13	9						
	11-23-4 W	3	1						

TABLE 1.—(*Continued*)

Line Number	Total Oil Production, Bbl.		Total Gas Production, Millions Cu. Ft.				Number of Oil and/or Gas Wells								Depth, Average in Feet	
								During 1937		At End of 1937						
	During 1937	Daily Average during Nov. 1937	To End of 1937	During 1936	During 1937	Maximum Daily during 1937	Completed to End of 1937	Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Oil and Gas[b]	Producing Gas Only	Total Producing	Bottoms of Productive Wells	To Top of Productive Zone
168	1,509,535															
169	320,656							39	8		21			21	3,005	2,972
					20							2	2		2,520	2,499
170	1,217,585														3,208	3,195
							173		29		132			132	3,509	3,507
															3,514	3,500
171	31,882		5,585													
												11		11	3,142	2,955
											7			7	3,345	3,279
							2				1			1	3,463	3,447
172			See under Southwest Kansas										4	4	2,747	2,744
173																
173*a*											39			39	3,464	3,390
													4	4	3,958	3,925
													1	1	4,094	4,055
174	5,037,862						5						1	1	4,109	4,094
175	1,647						1,110									
176	15,043										1			1	3,335	3,292
											1			1	2,832	2,803
177	162,000										1			1		2,363
											26			26	3,009	3,007
178							6						1	1	3,007	2,996
	1,404,020		76		53						1		2	3	3,360	3,323
179			600								95			95	3,298	3,274
	359,005												2	2	3,019	2.984
180							30		6		17			17	3,046	3,032
													6	6	2,943	2,927
	26,800														2,978	2,967
											33			33	3,200	3,140
181															2,395	2,340
													49	49	2,983	2,972
	1,981,360														2,960	2,925
							374		71				266	266	2,399	2,360
															3,414	3,412
182															3,444	3,440
													2		3,108	3,055
	1,668,598										118			118	3,304	3,301
															3,325	3,322
183															3,494	3,483
184	63,449	172														
185	60,040										28			28	2,435	2,330
186	95,469										21			21	2,340	2,300
187	100,911										14			14		2,800
188	30,473										52			52		2,365
189											40			40		2,532
													3	3		2,370
190																
191																
							4				1			1	4,399	4,378
192											3			3	4,430	4,428
193	9,876															
							5				5			5	3,841	3,815
194			42		42											
195	2,921												2	2		4,278
196	6,933,614										1			1	4,299	4,292
197	47,936															
198			24,436		5,802				2		6				3,544	3,540
													63	63	3,308	3,266
	8,310,489														3,375	3,365
											427				3,591	3,585
															3,784	3,775

TABLE 1.—(*Continued*)

Line Number	Pressure, Lb. per Sq. In.[d]			Character of Oil, Approx. Average during 1937	Character of Gas, Approx. Average during 1937		Producing Rock						Number of Dry and/or Near-dry Holes to End of 1937	Deepest Zone Tested to End of 1937	
		Average at End of		Gravity A.P.I. at 60° F.											
	Initial	1936	1937	Weighted Average	B.t.u. per Cu. Ft.	Gal. Gasoline per M Cu. Ft.	Name	Age[f]	Character[g]	Porosity[h]	Net Thickness, Average in Feet	Structure[i]		Name	Depth of Hole, Ft.
168													68		
169				35			Chat	Mis	IR		33	A	10		3,860
170							Lans. K. C.	Pen	L		21	Af			
							Chat	Mis	IR		13				
				43			Hunton	S. D	L		2	Af			
							Wilcox	Ord	S		14				
							Arbuckle	Ord	D				12		3,820
171	1,200		171	35			Chat	Mis	IR		87	A			
				35			Hunton	SD	L		66	A		Arbuckle	3,610
							Wilcox	Ord	S		16		1		
172							Fort Riley	Per	L						
													47		
173				36			Lans. K. C.	Ord	L		74	AE		Arbuckle	
173*a*							Viola	Ord	D		33				
							Simpson	Ord	S		39				
							Arbuckle	Ord	D		15		4	Arbuckle	
174													192		
175							Chat	Mis	IR		43				
176							Chat	Mis	IR		29	A		Arbuckle	
							Lans. K. C.	Pen	L			A		Arbuckle	3,520
177				37			Chat	Mis	IR						
							Chat	Mis	IR				5		
	1,040						Misener	Mis	DR						
178				41			Hunton	SD	L		24	A	0	Arbuckle	
	990						Chat								
179				37			Chat	Mis	IR		14	AF	7	Arbuckle	3,619
180							Chat	Mis	IR		16				
				37			Chat	Mis	IR		11				
							Viola	Ord	L		60				
				35			Lans. K. C.	Pen	L		55				
181							Chat	Mis	IR		11				
				32			Chat	Mis	IR		35				
				37			Lans. K. C.	Pen	L		39	D			
							Viola	Ord	L		2				
				32			Wilcox	Ord	S		4		37	Arbuckle	3,644
182				36			Chat	Mis	IR		53				
				42			Viola	Ord	L		3	Af			
							Wilcox	Ord	S		3				
				41			Arbuckle	Ord	D		11				
183				32			Viola	Ord	L			D		Pre-Cam	
184				34			Viola	Ord	L			D			
185				37			Viola	Ord	L			D		Arbuckle	
186				37			Chat	Mis	IR			MC		Arbuckle	
187				32			Viola	Ord	L			D			
188							Chat	Mis	IR			MC		Hunton	
189	785														
													0		
190							Fort Scott	Pen	L		21	D			
191				33			Miss. lime	Mis	L		2	L	1		
													10		
192				36			Arbuckle	Ord	D		26	D			
193															
							Viola	Ord	L						
194							Simpson	Ord	D		7				
195													125		
196							Lans. K. C.	Pen	L		4	A	3	Arbuckle	
197				37			Chat	Mis	IR		162				
	1,200		739	37			Chat	Mis	IR		10	Af			
198				42			Hunton	S-D	L		6				
				42			Arbuckle	Ord	D		9			Pre-Cam	

TABLE 1.—*(Continued)*

Line Number	Field, Survey, Township, Range	Age, to End of 1937		Area Proved, Acres				Total Oil Production, Bbl.	
		Years	Months	Oil	Oil and Gas[a]	Gas	Total	To End of 1937	During 1936
199	Hilger, 16-26-4 W	3	10	600			600	953,604	301,341
200	Lerado, 10-26-9 W	2	1	1,800			1,800	1,146,800	334,187
201	Nickerson, 4-22-7 W		6	40				198	
202	Yoder, 34-24-5 W	2	3		500		500	40,838	19,296
203	*Rice County*							31,936,218	11,216,771
204	Brandenstein, 10-19-10 W	4	2	160			160	309,516	42,395
205	Bredfeldt, 7-18-9 W		8	40			40	4,012	
206	Chase { 19-9 W	6	10						
	{ 20-10 W			4,800			4,800	13,836,088	3,499,950
207	Campbell, 28-19-9 W		1	40					
208	Cramm, 15-19-9 W		5	160			160	16,643	
209	Doran, 13-19-10 W	1	3	160			160	53,266	7,418
210	Edwards, 3-18-8 W	1	11	700			700	677,750	180,570
211	Galt, 8-18-7 W	2	3	40			40	16,072	9,755
212	Geneseo, 25-18-8 W	3	8	3,000			3,000	1,527,003	397,000
213	Guldner { 16-18-9 W	2	6	160			160		
	{							192,356	109,100
214	Haferman, 16-19-9 W	1	7	500			500	216,805	54,800
215	Keesling, 10-20-9 W	2	9	600			600	1,727,843	874,170
216	Lyons					40	40		
217	Orth { 27-18-10	5	6	600			600	} 436,402	} 84,100
	{ 27-18-10								
218	Ploog, 33-18-9 W	7	7	300			300	941,435	204,315
219	Raymond { 16-20-10 W	8	7 }	1,000			1,000	4,971,184	1,111,500
	{ 21-20-10 W								
220	Rickard, 22-18-9 W	2	3	40			40	29,988	12,722
221	Schartz (See Barton County)								
222	Silica (See Barton County)								
223	Soeken, 10-19-9 W	1	1	40			40	3,962	
224	Sterling, 4-22-8 W	1		40			40		
225	Stumps, 5-18-10		3	} 1,000			1,000	325,475	160,860
226	Stumps, 5-18-10	2	8						
227	Thurber, 22-21-9 W		2			40	40		
228	Welch	13	9	1,500			1,500	3,800,774	225,160
229	Welch, North, 23-20-6 W		6	160			160	9,749	
230	Wenke, 7-20-10 W	2	10	40			40	98,496	8,700
231	Wherry, 11-21-7 W	4	3	6,000			6,000	2,735,111	67,585
232	Wherry, East, 12-21-7 W		3	160			160	6,288	
233	*Rooks County:*							407,663	
234	Dopita, 31-8-17 W	3	9	160			160	26,989	1,900
235	Faubion, 12-6-18 W	1	10	80			80	18,390	4,020
236	Laton, 11-9-16 W	10	6	200			200	200,000	25,228
237	Nyra, 9-9-17 W		4	40			40		
238	Stockton, 35-7-17 W		8	160			160	7,678	
239	Webster { 15-8-19 W	3	3	40			40 }	50,000	
	{ 21-8-19 W	7	2	40			40 }		
240	Westhusin, 11-9-17 W	1	2	300			300	46,257	0
241	Zurich, 26-10-19 W	2	3	80			80	52,147	19,305
242	*Rush County:*							273,045	
243	Otis { 11-18-16	7	9			9,000	9,000		
	{ 10-18-16	3	5	500			500	242,755	36,170
244	Winget, 15-16-16			80			80	23,531	
245	*Russell County:*							35,811,431	6,500,426
246	Allon, 21-14-14 W		5	80			80	9,858	
247	Anschuts, 10-15-13 W	1	9	80			80	47,414	22,426
248	Atherton, 30-13-14 W	2	6	400			400	176,451	{ 16,488 } { 103,575 }
249	Balto, 32-13-14 W	1	9	120			120	69,419	
250	Benso, 9-14-15 W	1	10	40			40	15,771	6,311

TABLE 1.—(*Continued*)

Line Number	Total Oil Production, Bbl.		Total Gas Production, Millions Cu. Ft.				Number of Oil and/or Gas Wells								Depth, Average in Feet	
	During 1937	Daily Average during Nov. 1937	To End of 1937	During 1936	During 1937	Maximum Daily during 1937	Completed to End of 1937	During 1937		At End of 1937					Bottoms of Productive Wells	To Top of Productive Zone
								Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Oil and Gas[b]	Producing Gas Only	Total Producing		
199	539,041						40				34			34	4,067	4,062
200	803,427						43				37			37	4,256	4,237
201	198										1			1	3,287	3,243
202			y	y	y	y					6		5	11	3,501	3,450
203	2,316,218															
204	30,510						10				2			2	3,026	3,014
205	4,012										1			1	3,240	3,223
206	1,727,344												2	2	1,990	1,987
							266		3		228			228	3,284	3,246
207											1			1	3,208	3,195
208	16,643						3				3			3	2,947	2,876
209	45,848						7				4			4	3,311	3,291
210	497,180						38				33			33	3,282	3,278
211	5,185						6				1			1	3,230	3,205
212	806,157						60				54			54	3,175	3,132
213	47,668		626		468		1						1	1	3,025	2,884
							10				7			7	3,230	3,227
214	162,005						11				8			8	3,216	3,192
215	618,673						42				39			39	3,265	3,239
216			403		403		1						1		3,385	3,279
217	94,538												6	9	2,936	2,915
							13		2		9				3,243	3,240
218	140,096						13				10			10	3,271	3,252
219	831,184						69		2		60			60	3,140	3,130
															3,351	3,330
220	13,252						3				1			1	3,305	3,285
221																
222																
223	3,962										1			1	2,923	2,905
224											1			1	3,344	3,339
225	164,615						13				12			12	3,016	3,001
226											14			14	3,267	3,240
227							1						1		3,327	3,317
228	100,974						37							31	3,414	3,370
229	9,749						4							3	3,366	3,339
230	79,269						7		1					6	3,373	3,360
231	2,096,276						153							140	3,380	3,358
232	6,288						3							3	3,469	3,455
233																
234	22,983						6							5	3,217	3,212
															3,419	3,409
235	14,370						2							2	3,150	3,128
236	13,395						4		1					3	3,261	3,228
237							2							1	3,260	3,255
238	7,698													2	3,180	3,118
239	12,551													1	3,225	3,215
															3,445	3,442
240	46,257													7	3,242	3,231
241	30,257													4	3,349	3,340
242																
													35		3,509	3,507
243	204,000													20	3,536	3,527
244	23,531						4							3	3,247	3,243
245	11,811,431															
246	9,858													2	3,055	3,008
247	24,988						5				2			2	3,327	3,311
248	56,327						9				8			8	3,055	3,008
															3,289	3,284
249														3	3,220	3,200
															3,313	3,301
250	9,460						2				1			1	3,096	3,030

TABLE 1.—(*Continued*)

Line Number	Pressure, Lb. per Sq. In.[d]			Character of Oil, Approx. Average during 1937	Character of Gas, Approx. Average during 1937		Producing Rock						Number of Dry and/or Near-dry Holes to End of 1937	Deepest Zone Tested to End of 1937	
	Initial	Average at End of 1936	Average at End of 1937	Gravity A.P.I. at 60° F. Weighted Average	B.t.u. per Cu. Ft.	Gal. Gasoline per M Cu. Ft.	Name	Age[f]	Character[g]	Porosity[h]	Net Thickness, Average in Feet	Structure[i]		Name	Depth of Hole, Ft.
199				40			Viola	Ord	L		5	A	6	Arbuckle	4,348
200				40			Viola	Ord	L		19	A	6	Arbuckle	4,836
201							Lans. K. C.	Pen	L		44				
202				36			Chat	Mis	IR		49	A		Arbuckle	
203													239		
204				44			Lans. K. C.	Pen	L		12	D	8	Arbuckle	3,414
205							Arbuckle	Ord	D		17				
206				45			Admire	Pen	S		3				
							Arbuckle	Ord	D		38	A	27	Pre-Cam	3,772
207				46			Arbuckle	Ord	D		13				
208							Lans. K. C.	Pen	L		71				
209							Arbuckle	Ord	D		20		3		3,324
210				41			Arbuckle	Ord	D		4	D	5	Reagan	4,277
211				39			Arbuckle	Ord	D		25	A	5		3,662
212				39			Arbuckle	Ord	D		43	D	6		
213	1,040			45			Lans. K. C.	Pen	L		41				
							Arbuckle	Ord	D		3	D	3		3,873
214				48			Arbuckle	Ord	D		24		3		3,850
215				42			Arbuckle	Ord	D		26	A	3	Pre-Cam	4,103
216	1,045						Arbuckle	Ord	D		6				
217							Lans. K. C.	Pen	L		21				
218				43			Quartzite		S		3	D	2	Pre-Cam	
				45			Arbuckle	Ord	D		19	A	3	Reagan	
219				41			Lans. K. C.	Pen	L		10	D	7	Reagan	
				43			Arbuckle	Ord	D		21				
220				47			Wilcox	Ord	S		141		2	Arbuckle	
221															
222															
223							Lans. K. C.	Pen	L		18				
224				33			Conglomerate	Pen			4				
225							Lans. K. C.	Pen	L				1		
226				43			Arbuckle	Ord	D		38	A		Pre-Cam	
227							Conglomerate								
228				33			Chat	Mis	IR		44	A	6	Simpson	
229							Chat	Mis	IR		32	A	1		
230				40			Arbuckle	Ord	D		13				
231				38			Conglomerate	Pen	DR		27	MC	13	Arbuckle	
232							Conglomerate								
233				36									47		
							Lans. K. C.	Pen	L		5	A			
234				25			Arbuckle	Ord	D		10		1		3,840
235				36			Lans. K. C.	Pen	L		22				
236				40			Lans. K. C.	Pen	L		33	A			
237				34			Lans. K. C.	Pen	L		5		1		
238							Lans. K. C.	Pen	L		62				
239				35			Lans. K. C.	Pen	L		10				
				25			Arbuckle	Ord	D		3				
240							Lans. K. C.	Pen	L		11				
241				36			Lans. K. C.	Pen	L		9	A	3	Simpson	3,687
242													46		
243	1,140						Reagan	Cam	S						
				35			Reagan	Cam	S				3	Pre-Cam	3,762
244				39			Lans. K. C.	Pen	S		4		1		3,612
245													207		
246							Lans. K. C.	Pen			47				
247				37			Arbuckle	Ord	D		16		3		3,578
248				31			Lans. K. C.	Pen	L		47	A	1	Reagan	3,624
				40			Arbuckle	Ord	D		5				
249				31			Lans. K. C.	Pen	L		20				
				40			Arbuckle	Ord	D		12	A			
250				37			Lans. K. C.	Pen	L		66	A	1		

TABLE 1.—(*Continued*)

Line Number	Field, Survey, Township, Range	Age, to End of 1937		Area Proved, Acres				Total Oil Production, Bbl.	
		Years	Months	Oil	Oil and Gas^a	Gas	Total	To End of 1937	During 1936
251	Berrick, 6-15-13 W.	2	1	160			160	54,803	25,074
252	Big Creek, 30-14-14 W.	2	6	640			640	658,671	
253	Boxberger, 36-15-15 W.	2	1	160			160	86,152	59,540
254	Bunker Hill, 31-13-12 W.	2	2	160			160	28,670	10,628
255	Coralena, 17-15-13 W.	1	3	600			600	203,240	5,904
256	Dillner, 35-13-15 W.	7	8	40			40	61,154	0
257	Donovan, 10-15-15W.	2	10	40			40	16,388	11,143
258	Dubuque, 34-15-12 W.	2	2	160			160	95,043	56,500
259	Eichman, 34-15-13 W.	2	8	800			800	372,368	217,672
260	Fairport, 12-15-16 W.	14	2	3,600			3,600	12,490,347	929,418
261	Gorham, 13-14-15 W.	11	2	6,000			6,000	10,197,151	1,494,728
262	Gurney, 23-14-14 W.	2	10	1,800			1,800	437,776	134,800
263	Hall, 30-14-13 W.	6	2	800			800	781,955	244,000
264	Hall, North, 20-14-13 W.		2	40			40	992	
265	Letch, 34-14-13 W.	1	6	600			600	76,695	4,336
266	Neidenthal, 23-14-15 W.	3	5	600			600	634,092	236,439
267	Russell, 27-13-14 W.	3	10	1,200			1,200	3,212,118	{ 59,347 { 1,041,070
268	Sellens, 26-15-13 W.	8	6	1,200			1,200	1,776,236	356,812
269	Steinert, 21-15-15 W.	1	10	40			40	19,674	7,477
270	Trapp, 30-15-13 W.	1	9	7,000			7,000	3,910,186	400,239
271	Vaughn, 17-14-14 W.		8	200			200	113,746	
272	Williamson, 9-14-14 W.	1	11	160			160	20,866	11,363
273	*Scott County*							151,446	
274	Shallow Water, 15-20-33 W.	3	1	600			600	151,446	9,301
275	*Sedgwick County*							39,255,188	1,641,543
276	Andover South, 36-27-2 E.		{ 2	80		80	80 80		
277	Bentley, 19-25-1 W.	3	9	40			40	5,115	0
278	Cross, 26-25-1 W.	8	9	160			160	51,138	0
279	Derby					80	80		
280	Eastborough, 19-27-2 E.	8	5	1,000			1,000	{ 7,216,665	304,798
281	Goodrich, 16-25-1 E.	9	1	640			640	{ 1,849,921	109,920
282	Greenwich, 14-26-2 E.	8	8	700			700	8,513,655	
283	Kuske, 24-25-1 E.	8		40			40	132,561	
284	Oatville, 18-28-1 E.		2	40			40		
285	Robbins, 20-28-1 E.	8	7	420			420	2,511,311	442,782
286	Schulte, 6-28-1 W.	3	11	80			80	60,000	11,560
287	Valley Center { 1-26-1 W. } { 11-26-1 W }	9	5	1,500			1,500	18,863,289	577,400
288	*Stafford County*							3,106,280	715,106
289	Drach, 12-22-13 W.		2	40			40	1,690	
290	Gates, 27-21-13 W.	4	8	160			160	319,965	66,577
291	Jordan, 15-25-14 W.	1	2	160			160	51,169	0

TABLE 1.—(*Continued*)

Line Number	Total Oil Production, Bbl.		Total Gas Production, Millions Cu. Ft.				Number of Oil and/or Gas Wells								Depth, Average in Feet	
								During 1937		At End of 1937						
	During 1937	Daily Average during Nov. 1937	To End of 1937	During 1936	During 1937	Maximum Daily during 1937	Completed to End of 1937	Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Oil and Gas[b]	Producing Gas Only	Total Producing	Bottoms of Productive Wells	To Top of Productive Zone
251	29,729						4				3			3	2,945	2,894
252	470,855						34				31			4 31	3,022 3,184	2,982 3,180
253	25,712						5				4			4	3,151	3,147
254	16,042										4			4	2,981	2,965
255	197,336										9			9	2,881	2,790
											15			15	3,188	3,183
256									Abandoned 7-1-36					0	3,308	3,300
257	1,445						2				1			1	3,199	3,193
258	37,152													4	3,278	3,275
259	147,948						19							17	3,326	3,316
260	519,130													151	2,962 3,217	2,950 3,211
261	4,135,028										255			255	2,550 2,870 3,057 3,300 3,293	2,525 2,765 3,027 3,299 3,289
262											8			8		2,675
	282,833						25				21			21	3,006	3,001
263	324,000						8				28			28	3,085	2,985
											6			6	3,454	3,451
264	992										1			1	3,180	3,170
265	72,359										15			15		2,396
															2,880	2,831
266	153,007						17				15			15	3,250	3,246
267	863,532						61		2		3			3	3,204	3,195
268	312,000	718									49			49	3,286	3,280
							34				30			30	3,097 3,365	3,088 3,352
269	12,197						2				1			1	3,097	3,060
270	1,853,217						261				256			256	3,064 3,253	3,062 3,252
271	113,746										17			17	3,034	3,004
272											3			3	2,550	2,522
273																
274																
275	1,005,188						9				7			7	4,686	4,670
276													2	2	2,022	2,000
277	None										1			1	3,099	3,098
										Abandoned				1		2,911
278	12,638										2			2	2,730	2,690
279											1		1		2,232	2,215
280	268,844										49			49	2,970 3,242	2,956 3,238
281	188,864						29				22			22	2,616 3,020 3,337	2,614 3,010 3,334
282	443,881										43			43	2,868 3,327	2,865 3,321
283											1			1	3,017	3,013
284											1			1	3,491	3,489
285	82,179										56			56	3,102	3,090
286										Abandoned				0	3,653	3,652
287	106,678														2,692	2,572
288	1,126,084										78			78	3,368	3,366
289	1,690										2			2	3,705	3,693
290	51,600						8				4			4	3,714	3,698
291	51,169						5				4			4	3,727	3,722

TABLE 1.—(*Continued*)

Line Number	Pressure, Lb. per Sq. In.[d]			Character of Oil, Approx. Average during 1937	Character of Gas, Approx. Average during 1937		Producing Rock						Number of Dry and/or Near-dry Holes to End of 1937	Deepest Zone Tested to End of 1937	
	Initial	Average at End of		Gravity A.P.I. at 60° F.	B.t.u. per Cu. Ft.	Gal. Gasoline per M Cu. Ft.	Name	Age[f]	Character[g]	Porosity[h]	Net Thickness, Average in Feet	Structure[i]		Name	Depth of Hole, Ft.
		1936	1937	Weighted Average											
251				39			Conglomerate	Pen	L		51		1	Pre-Cam	3,250
252				35			Lans. K. C.	Pen							
							Arbuckle	Ord	D		4	A	3	Arbuckle	3,215
253				37			Lans. K. C.	Pen	L		4		1	Arbuckle	3,419
254				39			Lans. K. C.	Pen	L		16	A		Arbuckle	
255							Topeka	Pen	L		91				
							Arbuckle				5				
256				30			Arbuckle	Ord	D		8	A			
257				41			Lans. K. C	Pen	L		6	A	1	Arbuckle	3,350
258				40			Arbuckle	Ord	D		3	AC		Pre-Cam	
259				36			Arbuckle	Ord	D		10	A	2		3,443
260				38			Lans. K. C.	Pen	L		12	A		Pre-Cam	
				42			Gorham	Pen	S		6				
261				40			Tarkio	Pen	L		25				
							Topeka	Pen	L		5				
				38			Lans. K. C.	Pen	L		30	D		Pre-Cam	
				34			Gorham	Pen	S		1				
				35			Arbuckle	Ord			4				
262				38			Topeka	Pen	L		531	A		Pre-Cam	
							Lans. K. C.	Pen	L		5		4		
263				38			Lans. K. C.	Pen	L		100	A }	2	Pre-Cam	
				40			Arbuckle	Ord	DR		3				
264							Arbuckle	Ord			10				
265				38			Tarkio								
							Lans. K. C.	Pen	L		49	A			
266				40			Arbuckle	Ord	D		4	A	2		3,387
267				38			Lans. K. C.	Pen	L		9	D			
				33			Arbuckle	Ord	D		6		10	Pre-Cam	3,520
268				37			Lans. K. C.	Pen	L		9	A			
				38			Arbuckle	Ord	D		13		4	Pre-Cam	
269				35			Lans. K. C.	Pen	L		37		1		
270							Lans. K. C.	Pen	L		2				
							Arbuckle	Ord	D		1		5		3,629
271							Lans. K. C.	Pen	L						
272				35			Tarkio	Pen	L		28				
273															
274				26			Vaniman	Mis	L		16	A	2	Arbuckle	5,509
275													98		
276							Stalnaker	Pen	S		22				
							Wilcox	Ord	S		1				
277				34			Lans. K. C.	Pen	L		1	A		Arbuckle	
278				35			Lans. K. C.	Pen	L		40	MC		Ordovician	
279							Stalnaker	Pen	S		17	ML			
280				42			Chat	Mis	IR						
				44			Viola	Ord	L					Arbuckle	
281				35			Lans. K. C.	Pen	L		2				
				37			Chat	Mis	IR		10		7		
				38			Viola	Ord	L		3	D		Arbuckle	
282				39			Chat	Mis	IR		3	D		Arbuckle	
				42			Viola	Ord	L		6				
283							Conglomerate	Pen			4	ML			
284				45			Wilcox	Ord	S		2				
285				42			Chat	Mis	L			AC		Arbuckle	
286				44			Wilcox	Ord	S						
287							Lans. K. C.	Pen	L			120			
				43			Viola	Ord	L			2		Pre-Cam	4,275
288													72		
289				35			Arbuckle	Ord	D		12				
290				38			Arbuckle	Ord	D		16	A	4		
291				37			Lans. K. C.	Pen	L		5		1		

During 1937 the total production of the state reached a new high figure at 69¼ million barrels. This represents an increase over the previous year of approximately 12 per cent. By using the modern measuring stick of oil capacity, potentials, the phenomenal rise is even more emphatic. For, whereas Kansas in October 1933 had a potential capacity of only 200,000 bbl. per day, the figure at the end of 1937 had passed the three million mark.

In this connection it is interesting to record the inauguration of the use of the decline curve in determining potentials. This method was introduced by the State Corporation Commission after long continued research on the subject. During this year also began the policy of ratable taking of gas when the Otis gas field was prorated by the Corporation Commission.

OUTSTANDING POOLS

The most active drilling campaigns were in the Trapp, Bemis and Silica pools, which lie along the northeastern flank of the central Kansas

TABLE 1.—(*Continued*)

Line Number	Field, Survey, Township, Range	Age, to End of 1937		Area Proved, Acres				Total Oil Production, Bbl.	
		Years	Months	Oil	Oil and Gas[a]	Gas	Total	To End of 1937	During 1936
292	Kipp, 27-25-14 W.	1		40			40	22,201	
293	Richardson, 36-22-12 W.	7	3	1,200			1,200	2,384,928	487,493
294	Sittner, 33-21-12 W.		5	300			300	2,927	
295	Snider, 3-21-11 W.	1	9	320			320		
296	St. John, 23-24-13 W.	2	9	700			700	96,173 { 209,780	43,060 22,312
297	Zenith, 23-24-11 W.		4	160			160	11,767	
298	*Sumner County*							37,729,959	2,382,372
299	Anness, 2-30-4 W.		3	40			40	5,166	
300	Caldwell, 17-35-3 W.	8	8	160			160	1,164,971	44,609
301	Churchill, 25-31-2 E.	11	6	1,000			1,000	17,694,482	396,000
302	Oxford, 23-32-2 E.	10	5	800			800	13,302,694	
303	Oxford, West, 17-32-2 E.	11	8	160			160	447,194	
304	Padgett, 23-34-2 E.	11	3	1,800			1,800	1,600,000	104,953
305	Rutter, 21-33-2 E.	11	6	40			40	13,601	0
306	Vernon, North, 15-35-2 E.	22	6					100,902	
307	Wellington, 33-31-1 W.	8	1	1,200			1,200	2,504,685	667,441
308	Zyba, 7-30-1 E.		2	40			40		
309	*Trego County*							237,566	
310	Gugler, 36-12-21 W.	1	1	40			40	5,042	
311	Wakeeney, 14-11-23 W.	3	3	1,800			1,800	217,641	75,258
	Woodson County:								
312	Big Sandy, 13 to 23 of 26 S-14 E			400			400		
313	Hoagland, 26-23-14 E.			300			300		
314	Wiede, 32-23-15 E.			600			600		
315	Winterscheid, 15-23-14.			7,700			7,700		310,876
316	*Southwest Kansas* (Hugoton gas field)					1,500,000	1,500,000		

uplift. They all derive their production from the Arbuckle limestone, which still holds first position from the standpoint of productivity. At the close of 1936 the Trapp pool had 47 wells within an area of 1000 acres. One year later 286 wells were producing from an area of 7000 acres. Not only that, but drilling toward the south had extended the South Trapp area to cover 1200 acres and another discovery well classified as the Southwest Trapp pool outlined an eventually productive area, which threatens to rival the famous El Dorado pool of Butler County, with its 25,000 acres. A potential of almost 500,000 bbl. places the Trapp pool at the top of the list.

The Bemis pool lies 40 miles northwest of the Trapp pool, in Ellis County. It was discovered late in 1935, and had 25 wells at the close of 1936 in an area of 360 acres. One year later this pool covered 3200 acres, on which there were 148 producing wells. The limits had not been found and indications pointed to an eventual merging with the Shutts and possibly other pools of Ellis County. The potential production of the Bemis pool at the close of the year was 326,000 barrels.

TABLE 1.—(*Continued*)

Line Number	Total Oil Production, Bbl.		Total Gas Production, Millions Cu. Ft.				Number of Oil and/or Gas Wells								Depth, Average in Feet	
								During 1937		At End of 1937						
	During 1937	Daily Average during Nov. 1937	To End of 1937	During 1936	During 1937	Maximum Daily during 1937	Completed to End of 1937	Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Oil and Gas^b	Producing Gas Only	Total Producing	Bottoms of Productive Wells	To Top of Productive Zone
292	22,201										1			1	3,906	3,827
293	753,137						62				55			55	3,599	3,537
294	2,927						5				4			4	3,414	3,278
295	52,813										1			1	3,138	3,111
											4			4	3,242	3,224
296											11			11	3,620	3,588
	186,329						6				1			1	4,087	4,075
297	11,767										4			4	3,808	3,804
298	3,029,959															
299	5,166										1			1	4,401	4,394
300	43,800										4			4	4,784	4,778
301	94,482										71			71	1,867	1,855
302	618,694										67			67	2,893	2,020 2,890
303											4			4		
304	93,395										20		18	38	3,502	3,474
305											1			1		3,315
306											4			4	3,465	3,443
307	1,158,879										92			92	3,666	3,655
308											1			1	3,869	3,866
309	115,925															
310	5,042										1			1	3,838	3,830
311	96,000						16		1		12			12	3,627	3,619
312	20,681										20			20		
313	17,471										13			13		
314	15,609															
315	300,661	784									219			219	1,640	1,575
316			124,150		21,000	21,000	242						241	241	2,775	2,680

The Silica pool, which started out as the Isern pool in 1932, gradually extended its limits until it included the Schartz pool in Rice County and the Steckel and Kowalsky pools in Barton County. It had 175 wells at the close of 1936 in an area of 3200 acres. By the close of the succeeding year the number of producing wells had climbed to 402, with a potential capacity of 463,000 bbl. (on 6100 acres).

The record of these pools induced the oil operators to concentrate their efforts on the area upon and especially along the northern flank of the central Kansas uplift. Meanwhile, however, other parts of western Kansas were not neglected. Stafford County lies along the southwestern flank of the same large structural feature. For various reasons this county experienced a drilling campaign on a wide front. As a result three new pools were discovered and the old pools extended. In addition a new oil-producing horizon for that part of the state was found productive. The Misener sand, which has not been important up to date, was found in greater thickness than heretofore in the wells of the Zenith pool.

TABLE 1.—(*Continued*)

Line Number	Pressure, Lb. per Sq. In.[d]			Character of Oil, Approx. Average during 1937	Character of Gas, Approx. Average during 1937		Producing Rock						Number of Dry and/or Near-dry Holes to End of 1937	Deepest Zone Tested to End of 1937	
	Initial	Average at End of		Gravity A.P.I. at 60° F.	B.t.u. per Cu. Ft.	Gal. Gasoline per M Cu. Ft.	Name	Age[f]	Character[g]	Porosity[h]	Net Thickness, Average in Feet	Structure[i]		Name	Depth of Hole, Ft.
		1936	1937	Weighted Average											
292							Lans. K. C.	Pen	L						
293				41			Arbuckle	Ord	D		62	Af	7		3,765
294							Lans. K. C.				36		1		3,689
295				36			Lans. K. C.	Pen	L		27	A			
				42			Arbuckle	Ord	D		18				
296				33			Lans. K. C.	Pen	L		12				
				35			Arbuckle	Ord	D				5		4,160
297							Misener	Mis	S						
298													83		
299							Wilcox	Ord	S		7				
300				46			Wilcox	Ord	S		19	D		Arbuckle	
301				37			Stalnaker	Pen	S		25	Df		Pre-Cam	
302				37			Stalnaker	Pen	S						
				38			Arbuckle	Ord	D		3	A		Pre-Cam	
303							Arbuckle								
304				38			Chat	Mis	IR		28	AC	9	Arbuckle	
305							Chat	Mis	IR			AC		Arbuckle	
306							Chat	Mis	IR		22		6		
307				41			Chat	Mis	IR		11	MC	1	Arbuckle	4,133
308				47			Wilcox	Ord	S		3				
309													35		
310							Arbuckle	Ord	D						
311				39			Lans. K. C.	Pen	L		8	A	3	Arbuckle	
312							Bartlesville	Pen	S						
313															
314															
315							Miss. lime	Mis	L						
316	436	414	410		1,027	3	Big Blue	Per	L		10	MC	1	Mis	

New Producing Horizons

While the number of new horizons found in old pools would make an impressive list, an examination of the year's record shows no producing levels that had not been found in the state previously, but at some other place. Perhaps the outstanding development along this line was the finding of new supplies of oil in the Wilcox sand. Deeper drilling in the old Ritz-Canton area of McPherson County uncovered some good production in the Wilcox sand of Ordovician age. The same sand was also

Table 2.—*Summary of Drilling Operations in Kansas*

Important Wildcats Drilled in 1937

	County	Location			Total Depth, Ft.	Producing Horizon
		Sec.	Twp.	Rge.		
1	Barber	15	33	13	4,847	Viola
2	Barber	7	31	13	4,440	Viola
3	Barton	10	17	13	3,352	Arbuckle
4	Barton	4	16	12	3,326	Arbuckle
5	Barton	33	19	11	3,350	Arbuckle
6	Barton	10	17	11	3,289	Arbuckle
7	Barton	1	16	14	3,296	Arbuckle
8	Butler	13	28	6 E	2,740	Bartlesville
9	Butler	17	24	4 E	2,265	Lans. K. C.
10	Butler	27	23	4 E	2,212	Lans. K. C.
11	Chautauqua	6	33	12 E	1,986	Arbuckle
12	Cowley	20	32	5 E	3,097	Bartlesville
13	Cowley	16	30	4 E	2,802	Bartlesville
14	Cowley	3	30	4 E	2,828	Bartlesville
15	Cowley	30	32	6 E	2,247	Layton
16	Elk	35	31	10 E	2,040	Miss. lime
17	Elk	11	31	9 E	2,322	Miss. lime
18	Ellis	14	12	16	3,385	Arbuckle
19	Ellis	1	11	18	3,574	Arbuckle
20	Ellis	13	11	17	3,302	Arbuckle
21	Ellis	4	13	16	3,267	Lans. K. C.
22	Ellis	23	12	18	3,698	Arbuckle
23	Ellis	18	14	16	3,268	Lans K. C.
24	Greenwood	25	25	9 E	2,165	Miss. lime
25	Greenwood	6	26	10 E	2,161	Miss. lime
26	Greenwood	6	27	12 E	1,897	Miss. lime
27	Lyon	32	21	11 E	1,914	Bartlesville
28	McPherson	30	20	5 W	3,335	Chat
29	Pratt	11	27	13 W	4,310	Simpson
30	Reno	4	22	7 W	3,287	Lans. K. C.
31	Rice	7	18	9 W	3,240	Arbuckle
32	Rice	28	19	9 W	3,208	Arbuckle
33	Rice	15	19	9 W	2,947	Arbuckle
34	Rice	4	22	8 W	3,401	Chat
35	Rice	22	21	9 W	3,327	Conglomerate
36	Rice	23	20	6 W	3,366	Chat
37	Rice	12	21	7 W	3,469	Conglomerate
38	Rooks	9	9	17 W		
39	Rooks	35	7	17 W	3,180	Lans. K. C.
40	Russell	21	14	14 W	3,055	Lans. K. C.
41	Russell	20	14	13 W	3,180	Reagan
42	Russell	17	14	14 W	3,034	Lans. K. C.
43	Sedgwick	36	27	2 E	3,099	Wilcox
44	Sedgwick	32	28	2 E	2,232	Stalnaker
45	Sedgwick	18	28	1 E	3,491	Wilcox
46	Stafford	12	22	13 W	3.705	Arbuckle
47	Stafford	33	21	12 W	3,414	Lans. K. C.
48	Stafford	23	24	11 W	3,808	Wilcox
49	Sumner	2	30	4 W	4,401	Wilcox
50	Sumner	7	30	1 E	3,869	Wilcox

found productive in a number of scattered new pools such as the Anness pool in Sumner County, the North Andover and the Oatville pools in Sedgwick County.

A number of pools that had been producing from the Arbuckle added a second horizon when production was found in the Lansing-Kansas

TABLE 2.—(*Continued*)

Important Wildcats Drilled in 1937

	Farm Name	Drilled by	Initial Production per Day		Remarks
			Oil, U. S. Bbls.	Gas, Millions of Cu. Ft.	
1	No. 1 Holmes	Barbara Oil Co.	440		First oil in Med Lodge pool
2	No. 1 Gant	Pryor & Lockhart	1,351		Lake City pool
3	No. 1 Gory	Brauck & Duwe	255		Ainsworth south
4	No. 1 Poltzin	Palmer	950		Beaver north
5	No. 1 Schartz	Stanolind Oil	540		Ellinwood north
6	No. 1 Kraft	Price et al.	1,900		Kraft pool
7	No. 1 Ehrlich	Shell Petr. Co.	1,700		Trapp southwest
8	No. 1 McKaig	Landon et al.	90		McKaig pool
9	No. 1 King	Roth et al.	1,600		King pool
10	No. 1 Madden	Kahan et al.	30		Madden pool
11	No. 1 Foster	Robinson	15		Foster pool
12	No. 1 McKnab	McKnab	190		Frog Hollow pool
13	No. 1 Starkey	Brewer			Starkey pool
14	No. 1 Free	Shawver	100		Rock north pool
15	No. 1 Turner	Murta & Wilson	500		Turner pool
16	No. 1 Julian	Armer & Blair	500		Julian pool
17	Nc. 1 Sellars	Tyrrell et al.			Sellars pool
18	No. 1 Smith	Hall	572		Blue Hill pool
19	No. 1 Burnett	Wakefield	1,890		Burnett pool
20	No. 1 Cress	Lario	2,360		Cress pool
21	No. 1 Froelich	Truro	1,148		Emmeram pool
22	No. 1 Koblitz	Kor & Murfin	250		Koblitz pool
23	No. 1 Phillip	Buffalo	1,519		Victoria pool
24	No. 1 Henley	McGinnis	10		Henley pool
25	No. 1 Pedroja	Scott	160		Pedroja pool
26	No. 1 Taylor	West Kansas	75		Taylor pool
27	No. 1 Byrd	Sory et al.	25		Byrd pool
28	No. 1 Bornholdt	Bradley	131		Bornholdt pool
29	No. 1 Runyon	Atlantic	400		Iuka pool
30	No. 1 Pulse	Pulse et al.	156		Nickerson pool
31	No. 1 Bredfeldt	Cities Service	270		Bredfeldt pool
32	No. 1 Campbell	Skiles	160		Campbell pool
33	No. 1 Cramm	Comanche	1,720		Cramm pool
34	No. 1 Fair	Witt & Murphy			Sterling pool
35	No. 1 Wellman	Gerbrand		22½	Thurber pool
36	No. 1 Hubenett	Obins	250		Welch north pool
37	No. 1 Brothers	Holland	630		Wherry east pool
38	No. 1 Fike	Graham et al.			Nyra pool
39	No. 1 Hindman	Snowden & McSweeney	20		Stockton pool
40	No. 1 Hall	Billings	465		Allon pool
41	No. 1 Opdyke	Parks & Murfin	255		Hall north pool
42	No. 1 Vaughn	Empire	1,482		Vaughn pool
43	No. 1 Fee	Natl. Refining			Andover south pool
44	No. 1 Downs	Talbott		7½	Derby pool
45	No. 1 Martin	Murfin	45		Oatville pool
46	No. 1 Drach	Rust	945		Drach pool
47	No. 1 Sittner	Torrey & Feaster	1,408		Sittner pool
48	No. 1 Hartnett	Stanolind	974		Zenith pool
49	No. 1 Baird	Magnolia	378		Anness pool
50	No. 1 Blair	McKnabb	100		Zyba pool

Number of oil wells completed during 1937..........................	1,915
Number of gas wells completed during 1937..........................	128
Number of dry holes completed during 1937..........................	614

City limestones. Among them are the Weathered in Cowley County, and the Breford in Ellsworth County. Additional supplies of oil in the Arbuckle were found by deeper drilling in the Coralena pool and the Vaughn pool of Russell County, as well as the Walters pool of Ellis County. The Misener sand was added to the list of producing horizons in the Graber pool of McPherson County. The Pennsylvanian basal conglomerate was found productive in one well in the old Davidson pool of northeastern Barton County.

Deep Tests

Quite a number of deep tests in exploited territory as well as in wildcat territory were drilled during 1937. Many of these were drilled in an effort to furnish water-disposal wells. The interesting data on the thickness of the Arbuckle limestone and the Reagan sandstone furnished by such wells are much appreciated by geologists. The deep tests in Hamilton County at the western boundary of the state and in Sherman County farther north were among the most valuable. Other similar tests were drilled in Lane, Logan, Trego, Ford and Pawnee Counties. One wildcat in northern Rooks County was drilled into the pre-Cambrian rocks.

Acidization

The use of acid to stimulate limestone reservoirs to greater productivity was continued on a large scale during the year. Some experiments on sandstone reservoirs were carried on in various parts of the state. An important departure was made when the use of acid was applied to gas wells. In one case the increase of gas production was reported to be approximately 100 per cent.

Two interesting new gas developments were started. One of these may have far-reaching effects on the industry in a number of ways. One of the largest companies engaged in transporting gas acquired title to 4000 acres in Anderson County along the right of way of its principal pipe-line system. It is intended to use exhausted sands in that area for underground storage of gas at a point between the pools of southwestern Kansas and the market outlet farther east.

Geophysical Exploration

The search for new oil pools still relies in large part upon the effectiveness of geophysical prospecting methods. Twelve parties were operating more or less continuously in western Kansas during the year. The improvement in technique and the results of a number of years' experience now allows reflections to be secured from the main pay levels at great depth. Confidence in the validity of the data is growing and the methods of interpretation are becoming quite precise.

Oil and Gas Development in Kentucky in 1937

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(New York Meeting, February, 1938)

The oil industry in Kentucky during the year 1937 shows some improvement over that of 1936, although not to as marked a degree as 1936 over 1935.

Oil in Eastern Kentucky

In eastern Kentucky more than 150 new inside wells were completed in the pools of Estill, Powell and Lee Counties. Also, a number of wells were completed to be used as intake wells in repressuring operations. Repressuring is proving more successful in this area than was expected, as the producing formation was the Corniferous limestone. However, when the repressuring work was started, cores taken of this formation showed that the oil in the second and third pays was from a true sand, only the first pay in the top being a sandy lime formation.

In the Weir sand fields of Magoffin, Johnson and Lawrence Counties, continued repressuring operations caused an increase in the quantity of oil. These operations and the completion of 20 new wells in the Maxon sand and the Big lime (Mississippian) in Martin and Floyd Counties produced an increase in the oil production from eastern Kentucky of 100,000 bbl. over that of 1936.

As an illustration of what may yet be done in the fields of eastern Kentucky, one repressuring operation involving four oil wells and one pressure well produced an increase in production, or an additional recovery of 7200 bbl. of oil during the year. This amounts to a recovery of 2000 per acre for the 3.6 acres involved.

In other fields of eastern Kentucky, as in the Corniferous pools of Estill, Powell and Lee Counties, increases in the runs are noted as follows:

In the area of the Estill County pool from which the oil passes through the Revena pumping station, the production in 1935 was 88,175 bbl.; in 1936, was 102,849 bbl.; and in 1937 was 107,704 bbl. This pool was

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about 20 years old when repressuring was started. From the Ashley pool, Powell County, the production in 1935 was 36,580 bbl.; in 1936 it was 64,795 bbl. and in 1937 was 71,197 barrels. These increases were due solely to repressuring and the increases from the repressuring operation represents more than the differences in the figures given, as they

TABLE 1.—*Oil and Gas Production in Kentucky in* 1937

Line Number	Field, *County*	Age, Years to End of 1937	Area Proved, Acres				Total Oil Production, Bbl.
			Oil	Oil and Gas[a]	Gas	Total	To End of 1937
1	Big Sinking, *Lee, Estill, Powell and Wolfe*	18	14,100			14,100	37,318,*xxx*
2	Ida May, *Lee*	12	377			377	629,1*xx*
3	Pebworth, *Owsley*	14	60			60	69,*xxx*
4	Ross Creek, *Estill*	20	468			468	787,316
5	Goocey, *Lee*	17					74,5*xx*
6	Trabue, *Lee*	8					108,*xxx*
7	Ashley, *Powell*	20	1,091			1,091	2,991,*xxx*
8	Irvine, *Estill*	22	4,7*xx*			4,7*xx*	12,*xxx*,*xxx*
9	Wagesville, *Estill*	20	400			400	433,003
10	Campton—Stillwater, *Wolfe*	25	1,447			1,447	652,209
11	Buffalo Creek oil pool, *Owsley*	15	12			12	30,*xxx*
12	Island Creek, *Owsley*	Ab'n'd before 1934	20			20	9,899
13	Olympia, *Bath*	20	Depleted.	Abandoned since 1920.			
14	Menifee oil pool, *Menifee*	17[1]					231,835
15	Ragland oil pool, *Bath and Rowan*	36[2]					258,930
16	Cannel City, *Morgan*	25	600			600	378,507
17	Oil Springs, *Johnson-Magoffin*	18	6,100			6,100	9,033,701
18	Burning Fork, *Magoffin*	15	918			918	1,707,807
19	Blaine, *Lawrence, Johnson*	19	6,820			6,820	15,062,949
20	Elna, *Johnson*	17					1,553,831
21	Louisa pool, *Lawrence*	25	1,*xxx*		600	1,*xxx*	1,553,544
22	Ambrose-Weller, *Ohio*	12	600			600	3,951,500*y*
23	Isonville, *Elliott*	21	100	46	2,000	2,146	83,895
24	Big Sandy oil pool, *Floyd-Knott*	20	140			140	170,*xxx*
25	McKinney, *Lincoln*	17					4,502
26	Wayne, *Wayne-McCreary*	40	8,5*xx*			8,5*xx*	4,392,791
27	Logsdon Valley, LeGrande, Bonnieville, *Hart*	7	2,9*xx*			2,9*xx*	5,995,299
28	Livermore, *McLean*	2	545		20	565	1,229,907
29	Barrett Hill, *McLean*	8	250			250	873,815
30	Owensboro, *Davies, Ohio, McLean, Hancock, Breckenridge*	19	10,800			10,800	27,*xxx*,*xxx*
31	Henderson, *Henderson*	7	218			218	542,774
32	Muhlenberg, *Muhlenberg*	8					259,224
33	Bowling Green, *Allen, Warren, Simpson*	19					12,220,348

[a] Footnotes to column heads and explanation of symbols are given on page 313.

[1] Depleted; abandoned 1930; wells pulled.

[2] Depleted, abandoned 1931.

TABLE 1.—(*Continued*)

Line Number	Total Oil Production, Bbl.			Total Gas Production, Millions Cu. Ft.				Number of Oil and/or Gas Wells							
									During 1937		At End of 1937				
	During 1936	During 1937	Daily Average during Nov. 1937	To End of 1937	During 1936	During 1937	Maximum Daily during 1937	Completed to End of 1937	Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Oil and Gas[b]	Producing Gas Only	Total Producing
1	657,777	707,852[4]	1,8*xx*					2,454	50			2,454			2,2*xx*
2	49,509	58,080[5]	17*x*						15			11*x*			11*x*
3	2,*xxx*	2,*xxx*	6									15			15
4	17,192	21,508[6]	60									18*x*			8*x*
5	1,*xxx*	1,*xxx*	*x*									13			11
6	11,*xxx*	10,*xxx*	3*x*					15				15			15
7	51,*xxx*	52,*xxx*	15*x*					523			0	523			45*x*
8	152,*xxx*	154,*xxx*	4*xx*					1,1*xx*				1,0*xx*			1,0*xx*
9	21,476	26,161	21.3						50[10]			150			3*x*
10	8,863	7,776	15					275				275			7*x*
11	2,500	2,400	16					7			3	4			4
12	0	0	0					6	0		6				
13								20							0
14								150							0
15				100								100			0
16	1,001	678	3					75				75			14
17	218,066	221,192[7]	57*x*					1,055				1,005			1,033
18	59,110	54,954[8]	17*x*					159				159			159
19	472,875	479,776	1,36*x*					1,118	0	0		1,118			1,118
20	43,930	40,915	115					250			20	250			230
21	36,954	36,596	106					286			52	286			234
22	327,000	295,000*y*						190	0	0	190				190
23	2,164	3,147[9]	9					39			3	24	4	8	31
24	36,793	23,918	1*x*					51	6[11]	0	6	45			45
25	0	0						8	0	0[12]		4		4	0
26	31,104	35,074	8*x*					1,46*x*	1*x*						7,6*xx*
27	217,449	157,269	1,8*xx*					1,2*xx*				1,0*xx*		2,*xxx*	9*xx*
28	993,736	213,000		30*x*	0	30*x*	0.2	170	1	10		158		3	161
29	91,570	75,951						57	0	0		57			57
30	3,*xxx*,*xxx*	2,*xxx*,*xxx*	1,*xxx*					3,200							2,*xxx*
31	60,004	67,934	146					63				63			63
32	22,554	13,539	5*x*					20				20			20
33	186,876	184,787	5*xx*					2,026				1,*xxx*			1,*xxx*

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[4] Increase in Lee, Powell and Estill Counties due to repressuring, reconditioning, acidizing, and new inside drilling.
[5] Increase in production due to new wells and repressuring.
[6] Increase in production due to acidizing and reconditioning.
[7] Increase in production due to repressuring.
[8] Natural decline.
[9] Increase due to reconditioning of wells.
[10] Inside wells.
[11] During 1938 over 15 wells for Maxon and Big lime oil production will be drilled. The acidizing of lime wells is proving favorable.
[12] Field has been abandoned for several years.

also make up for the decline in production of the wells in the areas not under repressuring.

A small increase is noted in the production from the Ross Creek pool of Lee County. Here the reconditioning of old wells and acidizing of a few brought about an increase of over 4000 bbl. in the production of the field.

TABLE 1.—(*Continued*)

Line Number	Depth, Average in Feet		Oil Production Methods at End of 1937				Pressure, Lb. per Sq. In.[d]			Character of Oil, Approx. Average during 1937					Character of Gas, Approx. Average during 1937	
			Number of Wells					Average at End of		Gravity A.P.I. at 60° F.						
	Bottoms of Productive Wells	To Top of Productive Zone	Flowing	Pumping	Gas-lift	Injection into Reservoir[c]	Initial	1936	1937	Maximum	Minimum	Weighted Average	Sulphur, Per Cent	Base[e]	B.t.u. per Cu. Ft.	Gal. Gasoline per M Cu. Ft.
1	700–1,200	650–1,150		2,2*xx*		Air and Gas				42	37	40		P		
2	1,000–1,200	975–1,175		11*x*										P		
3														P		
4	550– 900	520– 870		8*x*										P		
5				11										P		
6	940–1,140	900–1,100		15						42	40	41		P		
7	600–1,000	550– 950		4*xx*										P		
8	120–1,000	85– 960		1,0*xx*												
9	100– 400	75– 375		3*x*		Air								P		
10				7*x*												
11	1,125	1,110		4						42.8	40.8	41.8		P		
12												39		P		
13																
14	1,040–1,250	1,020–1,230														
15	650– 850	625– 825														
16	1,800–2,000	1,780–1,980		11		[17]										
17	900–1,260	860–1,220		1,033	20	10 Air	180	300	300	38	34	36.5		P		
18	1,080–1,400	1,040–1,360		159						38	36	36.5		P		
19	760–1,060	700–1,000		1,118			550	*y*	360	38	34	36.5		P		
20	640–1,140	600–1,060		230						38	34	36.5		P		
21	1,600–1,900	1,575–1,875		234						40	37	38.5		P		
22	725	650- 700	0	190	0	15		10 points vacuum	10 points vacuum	35.9						
23	875–1,500	825–1,350		23									0.17	P		
24	1,000–1,500	950–1,475	2	6	39									P		
25	121– 360	101– 390														
26	400– 700	385– 680		6*xx*										P		
27	700– 850	780–1,300		9*xx*												
28	1,400	1,300–1,400		158		8		50	20	34.5						
29	1,250	800–1,200		57		5	320	74	40	37	34	35.5				
30	600–1,300			2,*xxx*						35						
31				63												
32	1,250–1,700			20												
33				1,*xxx*												

[17] Acid treatment has not been successful in this field.

Again, in the Big Sinking pool of Lee County, an increase of over 60,000 bbl. was brought about by the drilling of some 50 inside wells. This field comprises 8000 acres of proven area, mostly in large leases, some of which embrace as much as 3200 acres, and in the early development the inside locations were drilled very far apart. A study of the

TABLE 1.—(*Continued*)

Line Number	Producing Rock						Number of Dry and/or Near-dry Holes to End of 1937	Deepest Zone Tested to End of 1937		Reference to Text[j]
	Name	Age[f]	Character[g]	Porosity[h]	Net Thickness, Average in Feet	Structure[i]		Name	Depth of Hole, Ft.	
1	Corniferous	Dev, Sil	S, LS	Por	30	MC	3*xx*	Trenton	2,*xxx*	
2	Corniferous	Dev	S, LS	Por	20±	MC	4*x*	Devonian		
3	Corniferous	Dev	Ls	Por	20±	MC	1*x*	Devonian		
4	Corniferous	Dev	Ls	Por	20±	T	3*x*	Ordovician		
5	Corniferous	Dev	Ls	Por	20±		5*x*	Devonian		
6	Corniferous	Sil, Dev	Ls	Por	20±[18]	MC				
7	Corniferous	Dev	Ls	Por	40±	AF	4*x*			
8	Corniferous	Dev	Ls	Por	40±	AF	1*xx*	Ordovician		
9	Corniferous	Dev	Ls	Por	25±	AF	7*x*	Ordovician		
10	Corniferous	Dev	Ls	Por	25±	AD	8*x*	Devonian	2,190	
11	Big lime	Mis	Ls	Por	15	A	3	Devonian	1,962	K.G.S. New Oil Pools in Ky.
12	Big lime	Mis	L	Cav	10–40	MC	10	Devonian		
13	Silurian		L	Cav	10±	MC	7*x*	Ordovician		
14	Corniferous	Dev	Ls	Por	20±	MC	4*x*	Ordovician		
15	Corniferous	Dev	Ls	Por	25±	SC	1*xx*	Ordovician		
16	Corniferous	Dev	L	Por	20±	AF	2*x*	Devonian		
17	Weir	Mis	S	Por	35	D, A	9*x*	Ordovician	3,815	
18	Weir	Mis	S	Por	30	D	4*x*	Ordovician	3,900	
19	Weir	Mis	Sand	Por	60	D	1*xx*	Silurian		
20	Weir-Berea	Mis	S	Por	30	DF, A, S	15*x*	Devonian		
21	Berea	Mis	S	Por	20±	S	2*x*	Ordovician	4,975	Owens Bottling Co.
22	Jett sand	Mis	Sand	20%	40±	A	56	Trenton	4,020	
23	Weir	Mis Dev	S H Ls	Por	40± 20± 35±	A	8	Devonian	1,780	
24	Maxon—Big lime—Injun	Mis	S, Ls	Por Cav	15±	ML, MC, T	3*x*	Ordovician	3,706	
25	Corniferous	Dev	Ls	Por	18±	MC	4	Ordovician	855	Jillson—K.G.S. Series VI—1922
26	Beaver—Sunnybrook	Ord, Mis	Ls	Por	12	S	2*xx*	Ordovician	1,921	
27	Blue sand	Sil	L	Cav	15±	T, MC, A	2*xx*	Silurian		
28	Barlowe and Bethel	Mis	S	15% 20%	20	AF	17	Devonian	3,242	
29	Jett, Jackson, Barlowe, Bethel	Mis	S	15% 20%	2–75	AF	14	Devonian	3,250	
30	Fuqua, Stray, Pottsville, Jett, Barlowe, Jones	Pen Mis	S	Por 18–20%	2–75	AN, A, T, D	1,*xxx*	Ordovician		
31	Triplett, Jones	Pen, Mis	S	Por	30±	D, A	6*x*	Devonian		
32	Big lime	Mis	Ls	Por	20±	D	2*x*	Devonian		
33	Shallow sand, Corniferous, Deep sand	Mis Dev	Ls	Por	15±	D, T, A, MC	1,*xxx*	Ordovician		

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[18] In some of the Lee County oil pools as many as three different pays are encountered in the Corniferous. Pays vary in percentage of lime and silica contents.

recovery per acre in the area a few years ago showed that the greater yields had been recovered where the wells had been drilled very close together. As a result, some of the operators tried the drilling of inside wells, which apparently is proving worth while. The entire 60,000-bbl.

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Age, Years to End of 1937	Area Proved, Acres				Total Oil Production, Bbl.
			Oil	Oil and Gas[a]	Gas	Total	To End of 1937
34	Barren, *Barren*	18	3,667			3,667	2,500,029
35	Floyd gas field, *Floyd*	34	See Beaver Cr.		223,275	223,275	
36	Pike County gas field, *Pike*	7	[3]		55,000	55,000	
37	Martin County oil and gas field, *Martin*	40	90	20	86,300	86,410	24,444
38	Knott County, *Knott*	32	40		110,000	110,040	
39	Boyd County and Ashland, *Boyd*	13			16,640	16,640	
40	Perry gas field (Hazard), *Perry*	7			1,400	1,400	
41	Oneida—Burning Springs, *Clay*	12			7,000	7,000	
42	Burning Springs gas field, *Clay*	28					
43	Indian Creek gas, *Knox*	8	0	0	1,200	1,200	
44	Artemus-Himyar gas, *Knox*	7	0	0	{ 4,600E.W. { 5,000	5,000	
45	Red Bird gas field, *Bell*	7	0	0	600	600	
46	Williamsburg oil and gas field, *Whitley*	35		700		700	4,000
47	Big 6 gas, *Breathitt*	17			1,600	1,600	
48	Rothwell gas field, *Menifee*	36	0	0	15,360	15,360	
49	Powell gas, *Powell*	5					
50	Carlisle gas, *Gallatin, Carroll*	5					
51	Swamp Br. gas, *Johnson*	10	3	0	3,000	3,003	Not marketed
52	Flat Gap gas, *Johnson*	17			10,880	10,880	
53	Win gas, *Johnson*	20			1,980	1,980	
54	Cain, *Lawrence*	8			550	550	0
55	Green-Taylor gas, *Green and Taylor*	Ab'n'd 16					

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[3] Gas-producing horizons in Pike County are from 15 to 20 per cent deeper than in Floyd. The dip from Floyd County southeast to Pike County is approximately 30 ft. per mile.

TABLE 1.—(*Continued*)

Line Number	Total Oil Production, Bbl.			Total Gas Production, Millions Cu. Ft.				Number of Oil and/or Gas Wells							
									During 1937		At End of 1937				
	During 1936	During 1937	Daily Average during Nov. 1937	To End of 1937	During 1936	During 1937	Maximum Daily during 1937	Completed to End of 1937	Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Oil and Gas[b]	Producing Gas Only	Total Producing
34	66,900	78,318	14*x*								791				
35				*y*	*y*	*y*	*y*	1,230[13]	30	1*x*	[14]			1,1*xx*	1,1*xx*
36				*y*	*y*	*y*	*y*	179	4	0	2*x*			16*x*	1*xx*
37	3,849	20,595	160	*y*	*y*	*y*	*y*	296	43	0	0	12	2	282	296
38				*y*	*y*	*y*	*y*	214	32	0	20	See Beaver Creek pool		214	214
39				*y*	*y*	*y*		216	0	2*x*		2		214	1*xx*
40				*y*	*y*	*y*	*y*	7	1	0	2			7	3
41				*y*	*y*	*y*		30	0		26			26	26
42				*y*	*y*[19]	*y*	*y*	5						5	
43				*y*	*y*	*y*		7	1	0					7
44				*y*	*y*	*y*		19	1	0	2			9	7
45								3	0	0	3			3	0
46								30	0	0		25	0	5	5
47				*y*	*y*	*y*		14	3	10	1			3	3[23]
48				*y*	0	0	0	8*x*							0
49						[20]		2*x*	2					2*x*	
50														17	
51	0	0	0	*y*	*y*	*y*	*y*	22	0[22]	0	22	2	1	19	19
52				*y*	*y*	*y*	*y*	2*xx*	0	2*x*	1*xx*				7*x*
53				*y*[21]	*y*	*y*	*y*	28		2*x*					6
54	0	0		0	0	0	0	9	0	0	9			9	9
55								1*xx*							

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[13] Does not include oil wells. See Beaver Creek.

[14] Increase in depth due to development of Lower Devonian limestones.

[19] Gas production from this field is utilized only locally, for domestic purposes.

[20] Gas production from this field is utilized domestically in the small town of Stanton and as fuel to pump oil wells in Lee County.

[21] Three wells furnish domestic gas to Jackson, the county seat.

[22] During 1936 one well was deepened to the Big 6 horizon of Devonian-Silurian age and developed 200,000 cu. ft. open flow.

[23] This field is almost depleted.

TABLE 1.—(*Continued*)

	Depth, Average in Feet		Oil Production Methods at End of 1937				Pressure, Lb. per Sq. In.[d]			Character of Oil, Approx. Average during 1937					Character of Gas, Approx. Average during 1937	
			Number of Wells					Average at End of		Gravity A.P.I. at 60° F.						
Line Number	Bottoms of Productive Wells	To Top of Productive Zone	Flowing	Pumping	Gas-lift	Injection into Reservoir[c]	Initial	1936	1937	Maximum	Minimum	Weighted Average	Sulphur, Per Cent	Base[e]	B.t.u. per Cu. Ft.	Gal. Gasoline per M Cu. Ft.
34																
35	1,100–3,500[15]	900–3,100													1,150	
36	[16]															
37	1,100–3,250	700–3,000	4	10								38		P	1,150	
38	1,300–3,500	1,250–3,000													1,150	
39	2,200±	1,650±					*y*	*y*	*y*							
40	2,700–3,300	2,200–2,900														
41	1,550–1,700	1,525–1,675					305									
42																
43	1,550	1,500					See Pet. Ex.			See Pet. Ex.						
44	1,110±–2,100±	1,080±–2,000±					310	310	310						1,180	
45	3,500±	3,400±														
46	Oil 900± Gas 1,750±	Oil 850± Gas 1,700±					240							P		
47	1,750–1,900	1,725–1,875														
48	550– 700	500– 650														
49																
50	240– 350	225– 325					160		20							
51	1,800	1,425														
52	780–1,200	740–1,160														
53	700–1,100 2,100–2,500	670–1,070 2,050–2,450														
54	1,670–1,760	1,650–1,740														
55	390– 700	370– 680														

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[15] Less than 15 gas wells are not connected to pipe line. The average well is shut in four months of the year. Only during December, January, and February are over 90 per cent of the wells on line.

[16] Not until 1929–1930 was gas commercially developed in Pike County. Until this date some 30 wildcat shallow tests for oil had been drilled over the county.

increase, however, is not due solely to the drilling of inside wells, as a small extension on Miller's Creek to the westward from the field accounts for a fair portion of this increase. This extension in Big Sinking pool, the development of a small area in Floyd County and a larger area in Martin

TABLE 1.—(*Continued*)

Line Number	Producing Rock						Number of Dry and/ or Near-dry Holes to End of 1937	Deepest Zone Tested to End of 1937		Reference to Text[j]
	Name	Age[f]	Character[g]	Porosity[h]	Net Thickness, Average in Feet	Structure[i]		Name	Depth of Hole, Ft.	
34	2nd Sand Corniferous, Amber Oil Sand, Trenton	Mis, Dev, Sil, Ord	Ls	Por	10±	MC, T D, N	1,*xxx*	Ordovician		
35	Salt Sand, Maxon, Big lime, Big Injun, Devonian shale, Corniferous limestone	Pen, Mis, Dev	S, L Ls, H	Por Cav	15–550	A, D, MC, T N, S	95	Silurian	3,643	
36	Devonian shale, Salt sand, Maxon—Big lime, Big Injun	Pen, Mis, Dev	S L H	Por Cav	10–800	A, AM, H, MC, D, T, S	37	Devonian	4,181	
37	Oil, Maxon Gas, Salt sand, Maxon, Big Lime Dev. shale	Pen Mis Dev	S L, H,	Por Cav	10–600	A, F, D, T, MC, S	35	Devonian		
38	Salt sand, Maxon, Big lime, Big Injun, Dev shale	Pen, Mis, Dev	S, L, H	Por, Cav	20–500	A, AM, H, MC, D, T, S	19	Ordovician	3,706	
39	Salt sand, Maxon, Black shale, Corniferous	Pen, Mis, Dev	S, H, SL	Por	50± 400± 150±	T	29	Ordovician	4,669	K.G.S.—Ser. VI 1926—New Oil Pools in Kentucky
40	Salt sand, Big lime Brown shale	Pen, Mis, Dev	S, L, H	Por, Cav	50± 500±	MC	11	Devonian	3,637	
41	Corniferous	Dev	Ls	Por	20±	A, MC	16	Devonian	2,284	
42	Corniferous	Dev	Ls	Por	25±	A, D	1*x*	Devonian		
43	Big Lime	Mis	L	Cav	20	T	1	Mississippian	1,552	
44	Maxon, Brown shale, Corniferous	Mis, Dev	S H LS	Por	30± 175± 100±	A, AF, D	2	Devonian	2,225	
45	Big lime, Brown shale, Corniferous	Mis, Dev	L, H	Cav, Por	100± 175± 50±	MC	2	Devonian	3,725	
46	Salt sand, Big lime	Pen Mis	S L	Por, Cav	Oil 30± Gas 20±	A	1*x*	Ordovician	3,350	Jillson—K.G.S. Ser. VI—New Oil Pools in Kentucky
47	Big 6	Sil	S	Por	25±	A	1*x*	Silurian		
48	Corniferous, Ragland sand	Dev	LS	Por	40±	D	4*x* 1*x*	Ordovician		
49	Corniferous	Dev	LS	Por	20±	MC	1*x*	Ordivician	967	
50	Trenton	Ord	LS	Por	15±	D				
51	Maxon, Big lime, Shale	Mis, Dev	S L, H	Por, Cav	40± 350±	Depositional	0	Devonian	1,816	
52	Weir, Corniferous	Mis Dev	S, LS	Por	40±	D	2*x*	Ordovician	3,719	
53	Weir, Big 6	Mis, Sil	S, LS	Por	30±	A	8	Devonian		
54	Corniferous	Dev	LS	P	18	MC	7	Devonian	1,983	
55		Ord	LS	Por	20±					

County, are the only new fields or new production found in eastern Kentucky during the year.

In the Martin County development, 14 new wells completed to date are producing something over 200 bbl. daily. The production here is found in the Maxon sand of Chester-Mauch Chunk age (Mississippian). The sand has an average thickness of about 20 ft. and is found at a depth of some 1100 to 1400 ft. The structural condition is that of buried outliers on the old pre-Pennsylvanian land surface, and the oil appears to be a secondary accumulation in these outliers, derived probably from the Pennsylvanian muds deposited above. The wells have an initial production of some 10 to 40 bbl. natural. From the development to date, there appears to be only about 400 acres that will prove to be productive in this area. This oil was discovered in the normal development work by the gas companies owning acreage in that section.

The area in Floyd County where new production was found is in the vicinity of Betsy Layne, where the normal drilling of gas wells by the gas company located the production. The oil comes from the Big lime (Mississippian) and the initial production is from 15 to 50 bbl. daily.

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Age, Years to End of 1937	Area Proved, Acres				Total Oil Production, Bbl.
			Oil	Oil and Gas[a]	Gas	Total	To End of 1937
56	Cumberland—Clinton, *Cumberland, Clinton*	Ab'n'd					
57	Little Richland, *Knox*	Ab'n'd					
58	Ivyton, Licking and Mine Fork gas, *Magoffin*	17			6,840	6,840	
59	Needmore gas field, *Owsley*	17			6,400	6,400	
60	Morton's Gap, *Hopkins*	Field Ab'n'd	50			50	
61	Buford, *Ohio*	8	346			346	1,657,600
62	Habit, *Daviess*	7	100			100	217,000y
63	Lindsay Taylor pool, *Daviess*	Field Ab'n'd 8		15		15	22,577
64	Herbert, *Ohio*	17	350			350	425,986
65	Red Hill, *Daviess*	10	400			400	495,540
66	North Triplett gas, *Rowan*	33			1,200	1,200	
67	Bates Knob, *McClean*	2	350	20		350	136,146
68	Hackett, *McClean*	1	150	20		150	332,000
69	Island (New), *McClean*	6 Mo.	50			50	17,569

However, decline is rapid and acidizing methods are now being applied. About 15 wells were completed in the area.

OIL IN WESTERN KENTUCKY

During the year 1937 approximately 384 oil wells were drilled in the Owensboro field of western Kentucky, which embraces a number of pools in Ohio, Hancock, Davies, McLean, Henderson, Webster and Muhlenburg Counties. The production from this field during the year was 2,992,757 bbl., from the Chester sands of upper Mississippian and of Pennsylvanian age. The continued operation of repressuring units and the development of several new pools served to keep the production in this field fairly constant.

Repressuring operations when properly installed are proving successful, but generally speaking this has not been true of repressuring work in western Kentucky. As a result, a number of the operators have become somewhat discouraged and many feel that water-flooding will prove more successful. As a result a move was made to legalize water-flooding of

TABLE 1.—(*Continued*)

Line Number	Total Oil Production, Bbl.			Total Gas Production, Millions Cu. Ft.				Number of Oil and/or Gas Wells							
									During 1937		At End of 1937				
	During 1936	During 1937	Daily Average during Nov. 1937	To End of 1937	During 1936	During 1937	Maximum Daily during 1937	Completed to End of 1937	Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Oil and Gas[b]	Producing Gas Only	Total Producing
56															
57															
58				*y*	*y*	*y*	*y*	104	0	2*x*				104	5*x*
59							2,000	48		1*x*				3*x*	3*x*
60								5				0			Abandoned
61	283,600	243,600						125				125			125
62	*x*	17,000*y*						12	0	0		12			12
63								3		3		3			3
64	187,000	17,610						129	0	0		129			129
65	55,000	52,540						45	0	0		45			45
66				[24]				17		0	10			10	10
67	53,624	82,522		101.2*x*	1.2	100*x*		25	2	1		24	1	2	26
68	8,500	324,500		45				54	54	0			54		54
69		17,569						5	4	1		4			4

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[24] Gas not being marketed; average well, 187,000 cu. ft. This production will possibly find domestic market in town of Morehead, 3 miles to the east, in which the Morehead State Normal School is situated.

oil properties in Kentucky during the year. It is probable that the next few years will see this method of recovery in operation, and it is altogether possible that this method of recovery may prove more successful in the comparatively small pools of this area. The permeability varies greatly throughout the sand body and, as a consequence, because there are usually only a few leases involved in a given pool, water-flooding may prove to be the more practical method for increased recovery.

The new development in western Kentucky consists in the main of the discovery and development of the Hackett and the Island pools. The normal number of exploratory wells were drilled and about 50 intake pressure wells in the older pools.

The Hackett pool is about one mile east of Livermore, in McLean County, and covers approximately 150 acres. It was completely developed during the year, during which time 54 producing wells were completed. In 48 of these production was found in the "Jett sand" (Tar Springs sandstone) lying at a depth of from 1090 to 1200 ft. This sand has a thickness on an average of about 20 ft., and the initial production of the wells ranges from 20 to 650 bbl. daily. A considerable amount of

TABLE 1.—(*Continued*)

Line Number	Depth, Average in Feet		Oil Production Methods at End of 1937				Pressure, Lb. per Sq. In.[d]			Character of Oil, Approx. Average during, 1937					Character of Gas, Approx. Average during 1937	
			Number of Wells					Average at End of		Gravity A.P.I. at 60° F.						
	Bottoms of Productive Wells	To Top of Productive Zone	Flowing	Pumping	Gas-lift	Injection into Reservoir[c]	Initial	1936	1937	Maximum	Minimum	Weighted Average	Sulphur, Per Cent	Base[e]	B.t.u. per Cu. Ft.	Gal. Gasoline per M Cu. Ft.
56																
57	200– 500															
58	1,100–1,400	1,050–1,350														
59	900–1,200	850–1,150					317								1,085	1 qt.
60																
61	600	585		125		12x		10 points vacuum	10 points vacuum	35.5		35.5				
62	930	910		12		1				35						
63	1,125	1,085														
64	750	725		129				4	3	35		34				
65	1,015	970		45		2		Vacuum	Vacuum			34				
66	350	335					45									
67	400–1,700	340–1,670		24			360	340	30							
68	1,150–1,450	1,100–1,500		54			405		30	36.4						
69	1,470	1,450	2	2						36						

gas was found with the oil in this sand. A few of the wells yielded as high as 4,000,000 cu. ft. of gas per day. Because of the waste of this gas energy, the reservoir pressure of this sand declined from 405 lb. to 30 lb. at the end of the year.

The other six wells in the Hackett pool produced from the Bethel sand, lying at a depth of approximately 1475 ft. and having an average thickness of 15 ft. The wells in this sand had an average initial production of 50 bbl. The pool produced and marketed 324,500 bbl. of oil and 45,000,000 cu. ft. of gas during 1937.

The other entirely new development was also in McLean County, about two miles southeast of the town of Island. The production in this pool is found in a lenticular body of the "Jett sand" on the southeastern flank of a plunging anticline running a little east of north. The producing sand has an average thickness of 20 ft. and is found between 1450 and 1500 ft. Only four wells were completed in the pool during the year and these had an initial production varying from 75 to 350 bbl. The limits of the field have not been defined as yet, only one dry hole having been drilled to the south. This dry hole was extended on down to a depth

TABLE 1.—(*Continued*)

Line Number	Producing Rock						Number of Dry and/or Near-dry Holes to End of 1937	Deepest Zone Tested to End of 1937		Reference to Text[j]
	Name	Age[f]	Character[g]	Porosity[h]	Net Thickness, Average in Feet	Structure[i]		Name	Depth of Hole, Ft.	
56	Sunnybrook-Trenton	Ord	S LS	Por		A D		Cam-Ord	1,934	
57	Salt sand	Pen	S	Por	15±	A				
58	Weir, Black shale, Cornif., Salt sand Maxon, Big lime,	Pen Mis, Dev	S H L	Por Cav.	40± 450±	D, A, MC T	57	Ordovician	3,950	
59	Corniferous	Dev	LS	Por	40±	S MC	25	Devonian		Ky. W. Va. Gas Co.
60	Salt sand, Caseyville	Pen Mis	S L	Por	20± 6±	A F		Mississippian	2,132	
61	Pottsville	Pen	S	15%	15	Channel		Mississippian	1,250	
62	Fuqua Stray	Mis	S	18% 20%	20	A		Mississippian	1,350	
63	Jones, Hardingsburg, Salt sand	Mis	S	Por	40	AF	13	Mississippian	1,340	K.G.S. 1930 Ser. VI
64	Jett, Barlowe	Mis	S	12	5 to 30	T, A		Mississippian	950	
65	Jett	Mis	S	18	14	A		Mississippian	1,020	
66	Corniferous lime	Dev	LS	Por	11	MC	7	Ordovician	1,501	
67	Pottsville, Bethel, Barlowe, Bethel lime	Pen Mis	S L	12 15	20	AF	9	Mississippian	1,906	
68	Jeff, Bethel	Mis	S	20	22	A	11	Bethel (Bottom Chester)	1,525	
69	Jett	Mis	S		20	A	5	Devonian	3,817	

of 3817 ft., encountering at a depth of 3511 ft. the Devonian limestone. Small shows of oil were found in the Devonian limestone at 3525 and 3677 feet.

During the year a great deal of interest was manifested in the western part of the Western Coal Basin in northwestern Kentucky, toward the eastern and southern portions of which are the pools of the Owensboro field. The new interest is mainly evidenced in the western and deeper portion of this basin in Webster, Henderson, Union and Hopkins Counties. Most of the companies and operators that have become interested in this area and have acquired many hundreds of thousands of acres—practically all of the counties named being under lease—were companies operating in the Illinois Basin of which the Western Coal Basin is a part. Very little deep drilling has been done in the basin up to the present time, but several wells have been planned and a few started. These wells will be started for the purpose of testing the limestone lying below the Devonian black shale, commonly referred to by the oil fraternity in Kentucky as the Corniferous sand. Besides the well at Island that tested the Devonian limestone, another was completed in Hancock County by Galey & Flesher on the Holder lease, a short distance east of Indian Lake. The total depth of this well, however, was only 1908 ft., as it is on the east flank out of the deeper portion of the Western Coal Basin.

GAS

Eastern Kentucky.—No new areas producing gas were found in eastern Kentucky during the year 1937. In the areas of Floyd, Magoffin, Pike, Martin and Knott Counties, between 90 and 100 gas wells were completed for the various gas companies owning practically all of the acreage in these areas. No increase or decrease in the rate of development took place, practically all of the wells drilled being routine development by the companies involved. The 90 to 100 wells averaged about 600,000 cu. ft. of gas per well. Development in this area was retarded possibly to some extent by the fact that extensive development of the Oriskany gas fields in Kanawha County, West Virginia, lessened the demand to some extent for further development of gas in the eastern Kentucky field. However, the total deliveries of gas by the companies producing in eastern Kentucky varied very slightly from that of the preceding year. There is at present a larger volume of gas developed in the fields of eastern Kentucky than there is a market for, and yet the total area proved capable of producing gas is yet far from being fully developed.

Western Kentucky.—During the year, 128 gas wells were completed in the Owensboro field of western Kentucky. Gas comes from the same sands that produce the oil, which are from 119 to 1500 ft. in depth. The combined flow of 128 wells amounted to 78,892,000 cu. ft. per day, and the initial flow per well ranges from 25,000 to 8,000,000 cu. ft. The reservoir pressure was from 27 to 575 lb. In the oil and gas fields in the southern part of the state, composed of Allen, Barren, McCreary, Metcalf, Simpson, Warren, Hart and Wayne Counties, there was no new development and no efforts were made to apply recovery methods. The production has been regular, only a normal decline taking place.

Oil and Gas Development in North Louisiana in 1937

By H. K. Shearer,* Member A.I.M.E.

(New York Meeting, February, 1938)

Oil production in north Louisiana in 1937 was 28,668,070 bbl., an increase of 1,896,925 bbl., or 7.1 per cent over 1936, as against an increase of 178 per cent from 1935 to 1936. Gas production of 301,148 million cu. ft. from gas wells and 17,330 million cu. ft. of casinghead gas, a total of 318,483 million, was an increase of 33,483 million cu. ft., or 11.7 per cent over 1936.

Well completions numbered 716, with 411 oil wells, 175 gas wells and 130 dry holes; compared with 346, 109 and 78, respectively, in 1936. There were 58 wildcat dry holes. In addition to the wildcat producers described and tabulated with the fields, there were two small, shallow gas wells in Sabine and Tensas Parishes, which did not open fields of any present importance. At the close of 1937 there were only five wildcat tests actually drilling, with nine others shut down or temporarily abandoned.

Chief interest during 1937 was in development rather than discoveries. The only real discoveries were two deep gas and distillate fields, Bear Creek and Ruston. There were also three completions of gas-distillate producers from deeper formations in old fields, of which the most important was at Cotton Valley, one discovery of oil in a previously known gas sand and five or six extensions of some importance.

Geological Section

The columnar section in south Arkansas (Fig. 1, p. 317) also applies in north Louisiana, with a few changes noted below.

The oldest known formation in north Louisiana is a bed of rock salt. Except on salt domes, only one well at Rodessa has been drilled into this salt, but it has been penetrated by a number of wells in south Arkansas. Salt domes have been discovered near Vicksburg and Hattiesburg, Miss., and a deep well in Limestone County, Texas, has drilled into rock salt. In Louisiana the distance between the "interior salt-dome basin" and a salt dome of the "Gulf Coast salt basin" is hardly 60 miles. In short, evidence is accumulating to indicate that all of Louisiana, with the possible

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exception of the extreme northeast corner, is underlain by a thick bed of rock salt. There is no new information as to the exact age of the salt, and no change need be made in the statement in this review for 1931;[1] i.e., that it was probably laid down in early Mesozoic time. The old Llanoria continent, if it ever extended across Louisiana, must have sunk near the end of Paleozoic time, and its place was occupied by a great salt lake.

There is nothing known in Louisiana to correspond to the thick red beds of the Eagle Mills formation, the Smackover limestone and the Buckner formation, but future deep drilling should show whether these formations extend into this state, and their stratigraphic relations.

The predominantly marine beds, made up of various types of shale, sand and limestone, underlying the Travis Peak red beds, and having a thickness of about 3240 ft. at Rodessa, are called the Cotton Valley formation. Although differing lithologically, this formation corresponds closely in age and stratigraphic relations with the Schuler facies in Arkansas.

The Travis Peak formation includes the "lower Trinity red beds," with producing members near the top at Pine Island, Cotton Valley, etc.; and the Glen Rose formation (or subgroup) makes up the upper part of the Trinity. The lower Glen Rose, below the massive anhydrite, increases southward to a thickness of more than 1000 ft., and may be subdivided on the basis of lithology. The upper 500 ft., more or less, which includes all of the sand lenses and porous limestone beds producing at Rodessa, and producing zones a short distance below the anhydrite in other fields, is called the Rodessa member. The lower 500 ft. or more, consisting of black shale at the top, with various productive beds of oolitic limestone toward the base, is called the Pine Island member.

NEW FIELDS

Bear Creek.—The Seaboard Oil Corporation No. 1 McGee, sec. 3, T. 16 N., R. 6 W., near Bienville, Bienville Parish, had been abandoned in 1936 at 5905 ft., after testing dry in the Rodessa member of the lower Glen Rose. In 1937 it was deepened to 8017 ft.; casing perforated at 7323 to 7462 ft. in the Travis Peak red beds, where it tested estimated 70 million cu. ft. of gas per day; again plugged back and perforated at 6665 to 6695 ft. in the Pine Island member of the Glen Rose and completed in March 1937, making 67 million cu. ft. of gas per day with distillate, as the discovery well of the field. Two more wells were completed during the year, one in the Pine Island member and one in the Travis Peak, but there was no pipe-line connection and no commercial production.

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[1] *Trans.* A.I.M.E. (1932) **98**, 165.

Ruston.—The Arkansas Fuel Oil Company's No. 1 Causey, sec. 32, T. 19 N., R. 2 W., 5 miles northeast of Ruston, Lincoln Parish, had also been abandoned in 1936 at 4687 ft., having found salt water in the Rodessa member of the Glen Rose. The well was taken over by Lide & Greer and deepened to 5822 ft., testing salt water in the Travis Peak, but was plugged back and perforated in the Pine Island member at 5316 to 5320 ft. and completed in September 1937, producing 50 million cu. ft. of gas with distillate. No more wells have been drilled, and there is no pipeline connection.

Both the Bear Creek and Ruston structures were geophysical discoveries.

Extensions and Developments

Cotton Valley.—The Cotton Valley field, Webster Parish, a perfect unfaulted anticline, had long been considered one of the most favorable structures for deep testing. In 1936 the Ohio Oil Company's No. 6 Holloway, sec. 23, T. 21 N., R. 10 W. was drilled to 8556 ft. and made a drill-stem test in a sand at 8125 to 8149 ft., showing gas and distillate saturation, but this well was completed through perforations at 5556 ft. in the so-called Holloway sand near the top of the Travis Peak red beds. On Jan. 13, 1937, the Ohio Oil Company's No. 1 Bodcaw Lbr. Co., Acct. 4, sec. 28, T. 21 N., R. 10 W., was completed as the first producer in the deep sand at 8188 ft. This 8100-ft. sand is in the "lower marine beds" now known as the Cotton Valley formation. It is commonly called the Bodcaw sand, from this well (although there was a previously described "Bodcaw sand lens" about 100 ft. below the anhydrite, from which the gas is now practically exhausted). The principal Bodcaw sand is 40 ft. thick, and there are several thinner sands above and below. The productive area is much larger than in the older Buckrange and Rodessa member development, and the Bodcaw sand is productive more than 500 ft. down dip from the top of the structure. During last year, 29 wells were completed in the Bodcaw sand but none in the Holloway sand, which is lenticular in distribution. The Bodcaw sand wells produce up to 700 bbl. per day of 61° gravity "white oil," or distillate with 5 to 10 million cu. ft. of gas through small chokes. The gas-oil ratio averages 12,500 cu. ft. per barrel.

Lisbon.—The Lisbon field was discovered in the closing days of 1936 by the E. T. Oakes et al., No. 2 Patton Est., sec. 1, T. 20 N., R. 5 W., Claiborne Parish. The second well was completed late in March 1937, and the area quickly became the most active in north Louisiana, with 155 oil wells completed, of which 134 were in Claiborne and 22 in Lincoln Parish, and only one dry hole, which was junked without testing. The field was extended, mostly location by location, until it covers an area of at least 4000 acres, and is not defined in any direction, although the pro-

TABLE 1.—*Oil and Gas Production in North Louisiana*, 1937

Line Number	Field, *Parish*	Age, Years to End of 1937	Area Proved, Acres				Total Oil Production, Bbl.
			Oil	Oil and Gas[a]	Gas	Total	To End of 1937
1	Bear Creek, *Bienville*	¾	0	0	1,000	1,000	0
2	Bellevue, *Bossier*	17	1,360	0	160	1,520	9,860,430
3	Bethany-Waskom, *Caddo*[1]	22	20	*x*	*x*15,000	15,000	0
4	Caddo, *Caddo*[2]	34	32,500	*x*	*x*5,000	37,500	151,595,535
5	Carterville, *Bossier*	14	720	*x*	2,720	3,440	1,493,860
6	Clayton, *Concordia*	7	0	0	60	60	0
7	Converse, *Sabine*	6	2,000	*x*	*x*	2,000	1,719,610
8	Cotton Valley, *Webster*						15,973,650
9	Shallow	16	3,900	*x*	6,600	6,600	14,911,015
10	Deep	2	*x*	12,000	*x*	12,000	1,082,635
11	DeSoto-Red River (Bull Bayou), *DeSoto, Red River*	24	11,000	*x*	3,300	14,300	56,815,890
12	Driscoll (Union Church), *Bienville*[3]	2	0	0	640	640	0
13	Elm Grove, *Bossier, Caddo*	22	320	*x*	14,600	14,600	3,329,215
14	Epps, *East Carroll, West Carroll*	10	0	0	1,200	1,200	0
15	Haynesville, *Claiborne*	17	7,480	0	0	7,480	67,789,005
16	Holly, *DeSoto*	8	80	*x*	160	240	902,260
17	Homer, *Claiborne*	19	3,020	*x*	*x*	3,020	67,319,640
18	Lake Bistineau, *Bienville*	22	0	0	600	600	0
19	Lisbon, *Claiborne, Lincoln*	1	4,000	0	0	4,000	2,392,180
20	Monroe, *Morehouse, Ouachita, Union*	22	0	0	270,000	270,000	0
21	Pleasant Hill, *Sabine*	11	800	0	0	800	1,482,435
22	Richland, *Richland*	12	0	0	49,280	49,280	0
23	Rodessa, *Caddo*	8	9,400	[6]	7,800	17,200	38,223,180
24	Ruston (Causey), *Lincoln*[4]	¼	0	0	160	160	0
25	Sarepta-Spring Hill, *Bossier, Webster*	16	570	*x*	1,120	1,690	1,470,075
26	Shongaloo, *Webster*	17	70	0	5,680	5,750	105,930
27	Sibley (Dubberly), *Webster*	2	0	0	640	640	0
28	Simsboro (Montcalm), *Lincoln*[4]	3	0	0	320	320	0
29	Sligo, *Bossier*	16	180	0	7,300	7,300[7]	145,345
30	Sugar Creek, *Claiborne*	7	60	0	2,500	2,500	95,405
31	Sutherlin-Spider, *DeSoto*	3	0	0	320	320	0
32	Urania, *Grant, La Salle, Winn*	13	3,700	0	0	3,700	22,275,230
33	White Sulphur Springs, *La Salle*	10	80	0	0	80	12,290
34	Zwolle, *Sabine*	10	64,000[5]	0	0	64,000	13,188,285
35	Total		145,260	12,000	396,160	542,340	456,189,450

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[a] Footnotes to column heads and explanation of symbols are given on page 313.

[1] Includes the part of Bethany and Waskom fields in Louisiana; also Blanchard, Longwood, Greenwood, Cross Lake, Cedar Grove and Spring Ridge areas.

[2] Includes Mooringsport, Trees City, Vivian, Hosston, Pine Island, Gilliam and Dixie areas.

[3] Described as the "Arcadia field" in review for 1936.

[4] Simsboro (Montcalm) was described as the "Ruston field" in review for 1936. Note that present Ruston field is a 1937 discovery.

[5] Scattered production over 64,000 acres.

[6] Most Rodessa acreage produces both oil and gas; classification as oil or gas wells depends on gas-oil ratios.

[7] Sligo acreage does not include about 5000 practically proved acres under Barksdale Field, U. S. Army airport.

TABLE 1.—(*Continued*)

Line Numger	Total Oil Production, Bbl.			Total Gas Production, Millions Cu. Ft.			Number of Oil and/or Gas Wells							
								During 1937		At End of 1937				
	During 1936	During 1937	Daily Average during Dec. 1937	To End of 1937[8]	During 1936[8]	During 1937[8]	Completed to End of 1937[10]	Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Oil and Gas[6]	Producing Gas Only	Total Producing
1	0	0	0	28	0	28	3	3	0	3	0	0	0	0
2	228,575	280,130	775	2,258	45	49	390	12	12	*y*	110	0	2	112
3	0	0	0	17,445	768	677	179	4	*y*	*y*	0	0	53	53
4	2,381,065	2,362,130	6,480	135,774	1,528	1,697	4,168	97	80	*y*	1,199	0	32	1,231
5	51,825	43,810	114	16,980	13	13	146	0	6	*y*	54[11]	0	1	55
6	0	0	0	11	0	0	1	0	0	1	0	0	0	0
7	365,595	281,505	640	0	0	0	169	15	13	16	71	0	3	74
8	191,320	1,113,220	4,120	83,809	2,057	10,660	309	29	0	*y*	74	29	34	137
9	119,251	102,655	325	*x*	*x*	*x*	279	0	0	*y*	73	0	34	107
10	72,070	1,010,565	3,795	*x*	*x*	*x*	30	29	0	0	1	29	0	30
11	501,460	537,365	1,425	62,654	1,324	1,198	1,414	17	48	*y*	165	0	15	180
12	0	0	0	1,775	110	1,665	3	2	0	0	0	0	3	3
13	145,520	135,590	385	190,585	1,925	1,567	247	0	0	*y*	35	0	57	92
14	0	0	0	3,890	1,377	1,629	4	0	1	0	0	0	3	3
15	1,215,215	1,162,990	3,055	1,913	1,062	851	766	0	40	*y*	296	0	0	296
16	51,695	44,820	110	108	22	20	14	0	0	0	7	0	1	8
17	944,090	919,765	2,460	5,592	104	149	627	0	11	*y*	355	0	0	355
18	0	0	0	2,047	0	35	12	2	0	2	0	0	0	0
19	0	2,392,180	8,095	102	0	102	156	155	0	3	153	0	0	153
20	0	0	0	2,259,542	205,252	197,992	1,211	87	121	*y*	0	0	1,004	1,004
21	56,265	46,535	120	0	0	0	62	0	3	2	28	0	3	31
22	0	0	0	442,332	12,218	8,284	313	0	0	*y*	0	0	189	189
23	19,073,415	17,737,875	42,932	158,693[9]	42,412	70,626	460	107	0	35	329	*x*[6]	96	425
24	0	0	0	0	0	0	1	1	0	1	0	0	0	0
25	119,435	83,500	186	25,569	24	22	53	0	*y*	*y*	*y*[11]	*y*	*y*	*y*
26	5,980	4,030	11	71,015	147	169	91	0	0	0	1	0	13	14
27	0	0	0	0	0	0	4	1	0	4	0	0	0	0
28	0	0	0	1,986	279	1,707	2	0	0	0	0	0	2	2
29	20,005	125,340	343	57,296	8,757	14,298	103	22	0	*y*	7	0	95	102
30	0	95,405	375	31,942	5,466	5,059	15	10	0	*y*	3	0	12	15
31	0	0	0	221	103	0	5	0	0	2	0	0	0	0
32	1,012,595	1,024,735	2,880	6	0	0	486	19	0	*y*	258	0	0	258
33	0	0	0	0	0	0	12	0	0	0	0	0	0	0
34	407,090	277,145	870	164	2	2	332	1	20	4	49	0	0	49
35	26,771,145	28,668,020	75,376	3,573,736	284,995	318,478	11,758	584	355	73	3,194	29	1,618	4,841

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[8] Gas-production figures were supplied by the Louisiana Department of Conservation. Casinghead gas production is included, totaling 17,531 million cu. ft. in 1937, of which 14,267 million was from Rodessa. The grand total includes only 40,965 million cu. ft., as figures on casinghead gas have been kept only in recent years.

[9] Rodessa Oil Operators Committee estimates Rodessa gas production to Dec. 31, 1937, as 342,360 million cu. ft.; 154,234 million to pipe lines and 188,126 million to air.

[10] Numbers of completed wells and dry holes have been revised since the last review.

[11] Sarepta-Spring Hill producing wells are included in Carterville totals.

TABLE 1.—(*Continued*)

	Depth, Average in Feet		Oil Production Methods at End of 1937						Pressure, Lb. per Sq. In.[d]			Character of Oil, Approx. Average during 1937					Character of Gas, Approx. Average during 1937	
			Number of Wells							Average at End of		Gravity A.P.I. at 60° F.						
Line Number	Bottoms of Productive Wells	To Top of Productive Zone	Flowing	Pumping	Gas-lift	Air-lift	Misc.	Injection into Reservoir[c]	Initial	1936	1937	Maximum	Minimum	Weighted Average	Sulphur, Per Cent	Base[e]	B.t.u. per Cu. Ft.	Gal. Gasoline per M Cu. Ft.
1	6,695 7,879	6,665 7,320							y		y						y	y
2	370 1,035	360 1,010	0	110	0	0	0	G	y	y	y	21	18	19	0.80	A	970	0.34
3	1,000 to 5,900	[12]							1,880	y	y						y	0.22
4	1,000 to 4,000	[13]	0	1,199	0	0	0	G	y	y	y	46	14	25 40	0.50	A P	926	y
5	3,085 3,170	3,080 3,143	0	54[11]	0	0	0	0	y	y	y	44	38	42	0.27	P	1,046	0.33
6	1,438	1,415							y	y	y						984	0
7	1,922 3,232	1,617 3,150	0	71	0	0	0	0	y	y	y	42	39	40	0.15	P	y	y
8																M		
9	2,547 4,652	2,532 4,350	0	73	0	0	0	0	y	y	y	32	28	30	0.25	P	1,000	1.5
10	5,550 8,307	5,535 8,185	30	0	0	0	0	0	e3,930		y	52 60	50 63	51 61	y	P	1,173	0.54
11	825–3,500	[14]	0	165	0	0	0	G	y	0	0	44	36	40	0.25	P	y	y
12	5,880 7,218	5,862 7,160							2,375 2,830	y	2,055 2,600						y	y
13	840 2,496	804 2,469	0	35	0	0	0	0	y	y	y	32	28	29	0.40	M	1,025	0.15
14	2,344	2,336							y	y	y						998	0
15	2,680	2,665	0	296	0	0	0	G	y	y	y	38	31	35	0.40	P	1,100	1.5
16	2,851	2,838	0	7	0	0	0	0	y	y	y	40	37	38	0.22	P	y	y
17	1,345 2,065	1,280 2,040	0	355	0	0	0	G	y	y	y	39	31	35	0.63	P	1,100	1.5
18	2,018 2,553 5,235	1,993 2,544 5,190							2,310		2,310						y	y
19	5,275	5,250	129	24	0	0	0	0	e2,000	e2,000	e1,200	36	33	34	1.3	M	y	y
20	2,205	2,145							1,020	y	50 up						1,017	0–.60
21	3,237	3,175	0	28	0	0	0	0	y	y	y	42	38	42	0.30	P	y	y
22	2,447	2,349							1,125	y	50 up						1,060	0.34
23	5,600 6,100	5,560 6,075	271	28	30	0	0	0	e2,780	e1,586	e1,886	65	42	43 65	0.10	P	1,060	0.50
24	5,320	5,317							y	y	y						y	y
25	2,700	2,681	0	y[11]	0	0	0	0	y	y	y	28	25	25	0.32	M	1,000	0.07
26	2,680	2,665	0	1	0	0	0	0	y	y	y	30	28	29	0.35	M	971	0
27	5,600	5,560							y	y	y						y	y
28	5,301 5,700	5,282 5,664							2,100 2,620	y	y 2,475						y	y
29	[15]	[15]	6	0	1	0	0	0	1,890 2,200	y	1,100 2,100	41	40	40	y	P	1,050	0.3
30	4,400 5,730	4,370 5,700	8	0	0	0	0	0	1,800 2,310	y	y	37	32	35	y	P	1,125	0.56
31	2,850	2,840							1,200	1,200	1,200						y	y
32	1,530	1,520	0	249	0	9	0	0	y	y	y	22	18	19	0.30	A	y	y
33	804	794	0	0	0	0	0	0	y	y	y	21	19	20	y	A	x	x
34	2,500	2,100	0	49	0	0	0	0	y	0	0	42	38	40	0.10	P	y	y
35			439	2,744	31	9												

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[12] Different areas produce from Nacatoch at about 1000 ft.; Buckrange, 1950; Tokio, 2300; Rodessa, 4650; Pine Island, 5850; Travis Peak, 5900 to 6000.

[13] Production from Nacatoch at about 1000 ft.; Saratoga-Annona chalk, 1500 to 1600; Buckrange, 1825; Tokio-"Woodbine"-Paluxy, 2250 to 2400; and at Pine Island, from Rodessa Glen Rose, 2800 to 3000; Pine Island Glen Rose, 3700 to 3800; Travis Peak, 4000.

[14] Production from Nacatoch at about 800 ft.; Saratoga-Annona chalk, 1400; "Woodbine"-Paluxy, 2600; gas from Washita-Fredericksburg, 3500.

[15] Production from Nacatoch at about 845 to 883 ft.; Buckrange, 1710 to 1745; Tokio, 2445 to 2480; Fredericksburg(?), 2750 and 3100 to 3120; Rodessa, 4108 to 4275; Pine Island (Pettit zone), 5100 to 5200.

ducing formation becomes thinner and tighter toward the north and northwest. Production is from an oolitic limestone in the Pine Island member, at depths of 5125 to 5375 ft. The porous bed varies from 3 to 15 ft. in thickness, average about 10 ft., and most wells require large acid treatments before completion; so the production per acre will not be

TABLE 1.—(*Continued*)

Line Number	Producing Rock						Number of Dry and/or Near-dry Holes to End of 1937[10]	Deepest Zone Tested to End of 1937	
	Name	Age[f]	Character[g]	Porosity[h]	Net Thickness, Average in Feet	Structure[i]		Name	Depth of Hole, Feet
1	Pine Island Travis Peak	CreL	O, S	Por	y	A	0	Travis Peak	8,017
2	Nacatoch, Buckrange Rodessa	CreU CreL	S	Por	25?	AF	109	Cotton Valley	6,137
3	Nacatoch, Buckrange Rodessa, Pine Island	CreU CreL	S, O	Por	y	A	120	Cotton Valley	9,244
4	[13]	CreU CreL	S, C, O, L	Por	y	Af	929	Cotton Valley	6,351
5	Buckrange, Tokio	CreU	S	Por	9	MU	49	Paluxy	3,476
6	Jackson	Eoc	S	Por	25	N	6	Wilcox	3,705
7	Saratoga-Annona, Washita, Rodessa	CreU CreL	C, L	Por	x	Af	72	Travis Peak	8,517
8									
9	Buckrange Rodessa	CreU CreL	S S, A, O	Por	11	A	26		
10	Travis Peak Cotton Valley	CreL L. Mes.?	S	10 17	15 40	A	0	Cotton Valley	8,681
11	Nacatoch, Chalk, "Woodbine," Washita	CreU CreL	S, C	Por	y	AF	323	Lower Glen Rose	6,151
12	Rodessa Travis Peak	CreL	O, S	15	18 50	A	1	Travis Peak	7,693
13	Nacatoch, Ozan, Tokio	CreU	S	Por	y	A	42	Lower Glen Rose	5,382
14	"Monroe gas rock"	CreU	LS	Por	8	D	10	L. Cre. igneous	3,142
15	Buckrange	CreU	S	Por	25	A	62	Lower Glen Rose	5,092
16	"Woodbine"	CreU	S	Por	11	NL	28	Fredericksburg?	3,373
17	Nacatoch, Buckrange	CreU	S	Por	63	AF	196	Cotton Valley	4,504
18	Ozan, Tokio, Pine Island	CreU CreL	S O	Por	y	A	0	Travis Peak	5,625
19	Pine Island	CreL	O	20	10	N	1	Travis Peak	5,800
20	"Monroe gas rock"	CreU	LS	23	50	A	102	Cotton Valley	7,021
21	Washita	CreL	L, S	Por	16	Nf	25	Glen Rose	5,063
22	"Monroe gas rock," Tokio, Glen Rose	CreU CreL	S, LS	Por	76	A	40	Cotton Valley	9,986
			S, L, LS, O	5–35	5–80	AF	2	Rock salt	11,486
23	Rodessa	CreL	O	Por	10	A	0	Travis Peak	5,822
24	Pine Island	CreL	S	Por	11	A	19	Lower Glen Rose	5,120
25	Buckrange	CreU	S	Por	12	A	26	Lower Glen Rose	4,750
26	Buckrange	CreU	O	Por	40	A	0	Travis Peak	7,202
27	Rodessa	CreL							
28	Rodessa Pine Island	CreL	O, S	Por	30	A	2	Travis Peak	7,023
29	[15]	CreU CreL	S, O	Por	30	A	22	Travis Peak	6,112
30	Rodessa, Travis Peak	CreL	O, S	Por	13 50	A	5	Cotton Valley	8,616
31	Fredericksburg?	CreL	S	Por	10	AL	9	Lower Glen Rose	5,930
32	Cane River-Wilcox	Eoc	S	Por	9	MU	160	Tokio	6,463
33	Jackson	Eoc	S	Por	9	NF	8	Wilcox	2,435
34	Saratoga-Annona	CreU	C	Fis	x	Af	417	Lower Glen Rose	7,155

large, considering the depth and cost of drilling. Wells are spaced one to 20 acres. The oil contains more sulphur than usual in north Louisiana oils, so there was some difficulty in establishing a market, and the price is lower than the usual schedule for oil of similar gravity.

The structure as developed at present is a nose pitching south. There may be a closure to the north of present production, but oil accumulation seems at least partly due to tightening of the formation. Very little salt water is present, and structurally low wells are about as good as high ones. Structural relief between the highest and lowest wells is 200 ft. The original bottom-hole pressure of 2000 lb. has declined rapidly, and many wells have gone on the pump within a few months after completion.

TABLE 2.—*Summary of Drilling Operations in Louisiana*, 1937

Important Wildcats Drilled in 1937

	Parish	Location			Total Depth, Ft.	Surface Formation	Deepest Horizon Tested
		Sec.	Twp.	Rge.			
1	Bienville	15	16 N	10 W	5,233	Wilcox	Glen Rose-Pine Island member
2	Bienville	15	16 N	10 W	5,625	Wilcox	Travis Peak
3	Bienville	3	16 N	6 W	8,017	Claiborne	Travis Peak
4	Bienville	13	16 N	5 W	7,693	Claiborne	Travis Peak
5	Bienville	30	14 N	5 W	7,784	Claiborne	Travis Peak
6	Bossier	35	17 N	12 W	6,112	Wilcox	Travis Peak
7	Caddo	27	23 N	16 W	11,486	Claiborne	Rock salt
8	Caddo	11	17 N	15 W	9,244	Wilcox	Cotton Valley
9	Caddo	15	15 N	12 W	9,141	Wilcox	Cotton Valley
10	Caddo	10	15 N	15 W	6,503	Wilcox	Travis Peak
11	Claiborne	1	19 N	6 W	5,894	Claiborne	Travis Peak
12	Claiborne	29	22 N	6 W	6,147	Claiborne	Travis Peak
13	Claiborne	27	19 N	7 W	7,247	Claiborne	Travis Peak
14	De Soto	33	13 N	12 W	5,696	Wilcox	Glen Rose-Pine Island member
15	De Soto	24	11 N	14 W	5,930	Wilcox	Glen Rose-Pine Island member
16	Franklin	22	11 N	9 E	6,500	Pleistocene	L. Eocene?
17	Lincoln	32	19 N	2 W	5,822	Claiborne	Travis Peak
18	Lincoln	21	19 N	4 W	6,011	Claiborne	Travis Peak
19	Lincoln	22	16 N	5 W	6,210	Claiborne	Glen Rose-Rodessa member
20	Lincoln	11	17 N	4 W	7,023	Claiborne	Travis Peak
21	Richland	32	17 N	6 E	9,986	Claiborne	Cotton Valley
22	Sabine	8	9 N	13 W	5,503	Wilcox	Glen Rose-Rodessa member
23	Sabine	8	9 N	13 W	8,517	Wilcox	Travis Peak
24	Webster	28	21 N	10 W	8,188	Claiborne	Cotton Valley
25	Webster	32	21 N	10 W	8,681	Claiborne	Cotton Valley
26	Webster	2	17 N	9 W	7,202	Claiborne	Travis Peak
27	Webster	10	18 N	10 W	6,784	Claiborne	Glen Rose-Rodessa member
28	Webster	21	20 N	9 W	6,420	Claiborne	{ Glen Rose { anhydrite

Lake Bistineau.—The De Soto Oil & Gas Company's No. 1 Dunn & Olsen, sec. 15, T. 16 N., R. 10 W., in western Bienville Parish, had shown for production in 1936, and was completed Jan. 4, 1937, as the deep discovery well in this old, shallow gas field, estimated at 20 million cu. ft. of gas with dark colored distillate from oolitic limestone and sand at 5190 to 5235 ft., in the Pine Island member, having tested salt water

TABLE 2.—(*Continued*)

Important Wildcats Drilled in 1937

	Drilled by	Initial Production per Day		Choke or Bean, Fractions of an Inch	Pressure, Lb. per Sq. In.		Remarks
		Oil, U. S. Bbl.	Gas, Millions Cu. Ft.		Casing	Tubing	
1	De Soto O. & G. Co.	Distillate	20	2½-in. tubing	2,310		Deep sand discovery, Lake Bistineau field. Reported in last review, but officially completed in Jan. 1937
2	De Soto O. & G. Co.	Distillate	25	y	2,160		Perforated 5,100 to 5,190 ft.
3	Seaboard Oil Corp.	Distillate	67	O.F.	2,704		Discovery well, Bear Creek field. Plugged back and completed at 6,695 ft., in Pine Island zone of Glen Rose
4	Lide & Greer	Distillate	18		2,800		"Travis Peak" discovery, Driscoll field. Plugged back to 7,200
5	Hunt Oil Co.						Dry
6	Haynes Drlg. Co.						Dry, deepest test, Sligo field
7	R. W. Norton		19				Deepest test in north Louisiana, and first to reach salt off domes. Plugged back to 5,980
8	Gulf Ref. Co.						Dry
9	Prairie River Synd.						Dry
10	W. J. Hunter	20 dist.	2	2	y	y	Spring Ridge discovery, east of Bethany field. Plugged back to 5,199, completed in Rodessa zone, Glen Rose
11	Union Prod. Co.	205	y	2	1,400	y	Discovery oil well, Sugar Creek. Plugged back to 5,747
12	Max Hirsch et al.						Dry
13	Standard Oil Co. of La.						Dry
14	Benedum & Trees						Dry. On north flank of De Soto Field
15	Vaughn Prod. Co.						Dry. Spider area
16	Tensas-Delta O. Corp.						Dry
17	Lide & Greer	Distillate	50				Discovery well, Ruston field. Plugged back to 5,320
18	Easton & Belmont						Dry
19	E. H. Moore, Inc.						Dry. East of Arcadia salt dome
20	T. L. James & Co.						Dry. Deepest test and limits Simsboro field
21	Gulf Ref. Co.						Dry. First deep test in Richland field
22	Cox et al.	Distillate	10	y	y	y	Deep gas discovery, Converse field
23	Kirk-Green-Way, Inc.						Dry
24	Ohio Oil Co.	235 dist.	3	¼	2,950	2,600	Discovery well, Bodcaw sand at Cotton Valley
25	Standard Oil Co. of La.	400 dist.	4½	17/64	2,950	2,800	Southwest extension and deepest test at Cotton Valley. Perforated 8,594 to 8,611 ft.
26	Standard Oil Co. of La.	55 dist.	24				Deepest test, Sibley field. Plugged back to 5,680
27	Tidewater Oil Co.						Dry
28	Bass Drilling Co.						Dry

	In Proven Fields	Wildcats
Number of wells drilling Dec. 31, 1937	70	14
Number of oil wells completed during 1937	410	1
Number of gas wells completed during 1937	169	6
Number of dry holes completed during 1937	72	58

in the Rodessa member. A second well was completed during the year from the same zone, after drilling into the Travis Peak. There is no pipe-line connection.

Rodessa.—Major drilling activity in the Rodessa field in 1937 was in the Texas and Arkansas extensions, but 90 oil and 17 gas wells were completed in Louisiana. The field was extended northwest almost to the corner of the state by production from the Gloyd limestone and Mitchell sand. One dry hole was drilled in 1937, and it may be noted that, excluding old shallow tests and junked holes, the part of the Rodessa field in Louisiana has been developed with only two dry holes, both of which were located just southeast of the major fault. However, this does not mean that all wells listed as producers will be profitable.

Productive members or lenses, not all of which are present in any one part of the field, are, in descending order: the Hill sand, Neugent sand, Henderson sand, upper Gloyd oolitic lime, Mitchell sand, lower Gloyd oolitic lime, Dees oolitic and coquina lime and Young oolitic and coquina lime, all within 500 ft. below the base of the massive anhydrite, and collectively called the Rodessa member. A number of deeper wells have been drilled, but the Pine Island member and upper Travis Peak have not been found commercially productive in the Rodessa field.

The R. W. Norton No. 1 Payne well, sec. 27, T. 23 N., R. 16 W., was drilled to 11,486 ft., the greatest depth ever reached in north Louisiana, and was completed as a gas well in the Young zone after plugging back to 5796 ft. The location is near the fault, on the highest part of the Rodessa structure. This well had approximately 1060 ft. of Glen Rose beds below the base of the massive anhydrite, 1840 ft. of Travis Peak red beds, and 3240 ft. of the marine Cotton Valley formation, below which it penetrated 16 ft. into rock salt. There was apparently nothing corresponding to the Buckner anhydrite and Smackover limestone of Arkansas.

Total oil production declined a little from 1936, owing to proration, which was in force throughout 1937. In spite of proration, the pressure dropped very low in some parts of the field, 188 wells had shown more or less salt water by December 1937, and artificial lifting methods were becoming necessary. Little drilling remains to be done in 1938.

Sugar Creek.—Drilling to the 5700-ft. zone near the top of the Travis Peak continued in 1937 in this Claiborne Parish field. Oil was discovered in this sand by No. 1 Brown of the Union Producing Co. et al., sec. 1, T. 19 N., R. 6 W., producing 205 bbl. per day at 5747 ft. (plugged back from 5984 ft.). Only 3 of 10 wells drilled produce oil, 7 being gas wells. All of the oil wells and 5 gas wells were old gas producers, drilled deeper from the 4300-ft. zone.

Sligo.—In the Sligo field, Bossier Parish, development of the Pettit zone of the Pine Island member continued, with six oil and nine gas wells completed, but the area was limited by five dry holes, besides two others which were plugged back. There were also six gas wells in the Rodessa member at about 4300 ft., and one well opened a new oil-producing lens at 3118 ft. It is evident that Sligo and Sugar Creek will not make important oil fields from any formations so far tested.

Converse.—The Cox et al. No. 1 Whitney Corporation, sec. 8, T. 9 N., R. 13 W., in the shallow Converse field, Sabine Parish, was rated as a gas and distillate producer from the Glen Rose below the anhydrite at a depth of 5503 ft., Jan. 7, and is the deep gas-discovery well in this field, although not completed in a satisfactory manner. The Kirk-Green-Way, Inc. No. 1 Whitney Corporation in the same section was drilled to a total depth of 8517 ft., 1427 ft. into the Travis Peak, but was abandoned as dry. There were also 14 shallow oil wells completed in the Annona chalk, but production showed a decline.

Deep Gas Fields.—Little drilling was done in the deep gas fields discovered in previous years. At Driscoll, Bienville Parish, two gas and distillate wells were completed in the Travis Peak, and one test was dry. At Sibley, Webster Parish, one well was drilled into the Travis Peak, but was completed in the Rodessa member, where previous production was found. At Simsboro, Lincoln Parish, drilling resulted in two dry holes, limiting the field to the north and east. At Longwood, Caddo Parish, the discovery well was plugged back from the Travis Peak to the Pine Island member and re-completed, and a second well was drilled to the same zone.

The W. J. Hunter No. 1 Stoer, sec. 10, T. 15 N., R. 15 W., Caddo Parish, made a small gas and distillate well in the Rodessa member at 5125 ft., after drilling to a total depth of 6505 ft., in the Travis Peak. This well is on the east flank of the Bethany high, but may indicate a separate smaller structure. Two small shallow oil wells were also completed in secs. 5 and 6, T. 16 N., R. 16 W., on the east flank of the Bethany gas field.

Old Fields.—In the old Caddo fields, 93 shallow oil wells, 4 gas wells and 27 dry holes were drilled. Among these were 34 oil wells near Pine Island, all completed in the chalk rock, mostly as a result of acid treatment; and 9 oil wells were completed in the Dixie pool.

In and around the De Soto-Red River field, 15 oil wells, 2 gas wells and 14 dry holes were completed. The Grogan Oil Company's No. A-1 Ramsey, sec. 36, T. 11 N., R. 11 W., completed July 8, flowing 360 bbl. per day at 2961 ft., appeared to open an extension or separate pool of some importance, but later drilling in the vicinity resulted in only one small gas well and seven dry holes. On Dec. 30 the Petroleum Heat & Power Corporation's No. 1 Kavanaugh, sec. 7, T. 11 N., R. 11 W. flowed 105 bbl. per day at 2841 ft., as a southwest extension of the old field. Also, in De Soto Parish, dry holes between 5000 and 6000 ft. deep and into the lower Glen Rose, were drilled in sec. 33, T. 13 N., R. 12 W., on the northwest flank of the De Soto field; in sec. 24, T. 11 N., R. 14 W., Spider area;

in sec. 28, T. 11 N., R. 12 W., Pelican area; and in sec. 7, T. 14 N., R. 14 W., Gloster area.

At Zwolle only one producing well was completed in 1937. The Hunter Co., Inc., No. 1 Bowman Hicks, sec. 12, T. 7 N., R. 13 W., flowing 20 bbl. per hour on Nov. 28 from a depth of 2492 ft., opened an extension to the south of the Zwolle townsite area, and caused additional drilling to be started near the end of the year.

In the Monroe gas field 87 producing wells were completed; 19 in Morehouse Parish, 21 in Ouachita and 47 in Union. Most of the wells drilled in recent years have been along the north and west edges of the field, where pressure remains high but volumes are relatively low. Many of the wells completed have open-flow capacities of only one to five million cubic feet per day. The Monroe field may be expected to lose some of its dominant importance to the newer deep gas fields, but in 1937 it still produced more than 62 per cent of the north Louisiana total.

Deep Wells.—Besides the deep tests included in field descriptions, a few other deep wildcats are worth mentioning. In Caddo Parish two more tests were drilled into the Cotton Valley formation. The Gulf Refining Company's No. 1 Hatcher, sec. 11, T. 17 N., R. 15 W., on the south edge of the old Cross Lake shallow gas field and about 7 miles southwest of Shreveport, was drilled to 9244 ft., penetrating about 2260 ft. of Travis Peak red beds and 980 ft. of the Cotton Valley formation. The Prairie River Syndicate's No. 1 Hutchinson, sec. 15, T. 15 N., R. 12 W., in the Caspiana area southwest of the Elm Grove field, went to 9141 ft., with about 2530 ft. of Travis Peak and 766 ft. into the Cotton Valley. Both of these wells are reported to have had very little porosity in the upper Travis Peak and Cotton Valley sands.

The Gulf Refining Company's No. 15 Rhymes, sec. 32, T. 17 N., R. 6 E., in the center of the Richland gas field, was abandoned at 9986 ft. in April, being the deepest test in north Louisiana up to that time. It found the lowest Glen Rose anhydrite at 3449 ft., had 5280 ft. of lower red beds (Travis Peak) and the last 305 ft. consisted mostly of limestone, evidently representing the Cotton Valley formation.

Proration

Proration based on acreage, bottom-hole pressure and gas-oil ratio has been in effect throughout 1937 in the Rodessa and Lisbon fields, and gas withdrawal from gas wells is limited by state law on the basis of acreage and open-flow potential. Allowables have been sufficiently high to avoid any serious complaint, and are in fact as high as the fields can stand without actual damage. The waste of gas at Rodessa has been greatly reduced since proration went into effect on Sept. 15, 1936.

PROSPECTS FOR 1938

Activity will continue at Cotton Valley and Lisbon, but most of the drilling at Rodessa has been completed. The number of wells drilled will probably decline somewhat in 1938, unless discoveries are made early in the year.

Exploration in recent years, since the discovery of the Rodessa field, has developed a large gas reserve on deep structures and in previously untested formations under the old shallow fields; and future discoveries of the same type are to be expected. Except in the Lisbon field, most of the production is gas and distillate, or light oil, which can be produced only with high gas ratio. Hence the present value depends largely on ability to find a market for the gas that must be produced in order to obtain any oil. East Texas also has a temporary oversupply of gas, and considerable quantities are likely to be found by deep drilling in south Arkansas.

However, the Monroe field has been producing gas for 22 years and is now definitely on the downgrade. The Richland field has been almost depleted in 12 years. Gas lines radiate from Monroe all over the southeastern states, and as far north as St. Louis. Even allowing for prospective discoveries, it is difficult to foresee an abundant supply of gas for more than 20 years in the future. Properties capable of producing gas with large quantities of natural gasoline, distillate or light oil, even at depths exceeding 8000 ft., have real value and must become profitable to operate within a very few years.

Oil and Gas Development in South Louisiana

By Benjamin C. Craft,* Member A.I.M.E.

(New York Meeting, February, 1938)

As predicted, during 1937 South Louisiana witnessed one of the most active drilling campaigns in the history of the area, resulting in the discovery of 14 new fields. The economic importance of 10,000-ft. production was far-reaching and the objective depths placed on some wildcats was 12,000 feet.

Most of the important discoveries and deep tests were in the delta area between the Atchafalaya and Mississippi Rivers, where the upper Miocene sands were found productive between 10,000 and 11,000 ft. The casing program on these wells usually called for a protection string of 9⅝-in. casing at approximately 9500 ft. Drilling barges with the heaviest equipment were used where water transportation was available.

The oil production for South Louisiana during 1937 was 62,147,690 bbl., as compared with 51,968,727 bbl. during 1936, an increase of 19.5 per cent. There were 281 oil and gas wells and 172 dry holes completed during 1937 as compared with 262 oil and gas wells and 135 dry holes during the previous period.

New Fields

Gibson.—The first discovery for the year was in the Gibson area, where Shell Petroleum Corporation's Realty Operators No. 1, sec. 18, 17 S., 15 E., Terrebonne Parish, was completed flowing 780 bbl. of 38° A.P.I. oil daily through a $^{14}/_{64}$-in. choke with a tubing pressure of 1700 lb. Production is from upper Miocene sand found from 9461 to 9483 feet.

Abbeville.—The discovery well for the Abbeville field was Continental Oil Company's Hebert No. 1, sec. 20, 12 S., 3 E., Vermilion Parish, completed flowing 50 bbl. of distillate and 2 million cubic feet of gas through a $^{3}/_{16}$-in. choke with a tubing pressure of 2550 lb. The well was plugged back from 12,216 ft. in the Chickisawhay, and is producing through perforations from upper Miocene sand found from 7668 to 7682 ft. Later in the year, the same operators completed Brookshire No. 1, sec. 66, 12 S., 3 E., flowing 366 bbl. of 42° A.P.I. oil per day through a $^{3}/_{16}$-in. choke with a tubing pressure of 1800 lb. This well was com-

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pleted through perforations at 7884 to 7890 ft. after being drilled to 11,909 feet.

South Roanoke.—A new distillate-producing area was discovered in Jefferson Davis Parish when Shell Petroleum Corporation's Sturdevant No. 1, sec. 25, 10 S., 4 W., tested 15 bbl. of distillate and 3 million cubic feet of wet gas per day with a tubing pressure of 2850 lb. The well was drilled to 9749 ft. but production was obtained from the upper Miocene sand found from 8540 to 8550 ft. The first oil well was Union Sulphur Company's T.R.S. Farms No. 1, sec. 23, 10 S., 4 W., completed flowing 50 bbl. of 47° A.P.I. oil and 3 million cubic feet of gas per day from sands at a depth of 8560 to 8563 feet.

Lirette.—In May, Humble Oil and Refining Co. completed the deepest producing well in the world. Ellender No. 1, sec. 32, 19 S., 9 E., Terrebonne Parish, was drilled to a total depth of 12,165 ft. and completed in upper Miocene sand found from 11,620 to 11,630 ft. The initial produc-

TABLE 1.—*Oil and Gas Production in South Louisiana*

Line Number	Field, *Parish*	Age, Years to End of 1937	Area Proved, Acres				Total Oil Production, Bbl.
			Oil	Oil and Gas[a]	Gas	Total	To End of 1937
1	Jennings, *Acadia*	37	320	0	0	320	55,278,555
2	Anse La Butte, *St. Martin*	36	35	0	0	35	890,001
3	Welch, *Jefferson-Davis*	35	50	0	0	50	618,795
4	Vinton, *Calcasieu*	28	265	0	0	265	42,547,281
5	Edgerly, *Calcasieu*	26	215	0	0	215	8,438,115
6	Pine Prairie, *Evangeline*	26	10	0	0	10	20,000
7	Houma, *Terrebonne*	26	0	0	720	720	
8	Bayou Bouillon, *St. Martin*	22	20	0	0	20	385,233
9	New Iberia, *Iberia*	21	100	0	0	100	8,643,530
10	Lockport, *Calcasieu*	14	270	0	0	270	14,178,292
11	Starks, *Calcasieu*	13	50	0	0	50	2,431,713
12	Sulphur, *Calcasieu*	12	60	0	0	60	11,288,899
13	Sweet Lake, *Cameron*	12	250	0	0	250	3,450,051
14	Fausse Point, *Iberia*	11	10	0	0	10	32,837
15	Hackberry, *Cameron*	10	100	0	0	100	3,828,121
16	East Hackberry, *Cameron*	10	140	0	0	140	18,694,847
17	Sorrento, *Ascension*	10	20	0	0	20	788,836
18	White Castle, *Iberville*	9	50	0	0	50	2,270,289
19	Port Barre, *St. Landry*	9	75	0	0	75	6,775,863
20	Dog Lake, *Terrebonne*	9	40	0	0	40	1,099,534
21	Bayou Blue, *Iberville*	9	40	0	0	40	63,539
22	Black Bayou, *Cameron*	9	100	0	0	100	4,688,533
23	Lake Pelto, *Terrebonne*	9	80	0	0	80	570,026
24	Lake Barre, *Terrebonne*	9	100	0	0	100	15,098,689
25	Caillou Island, *Terrebonne*	8	370	0	0	370	16,962,108
26	Cameron Meadows, *Cameron*	7	100	0	0	100	4,927,000
27	Choctaw, *Iberville*	7	30	0	0	30	1,730,339
28	Lake Washington, *Plaquemines*	7	200	0	0	200	2,075,220

[a] Footnotes to column leads and explanation of symbols are given on page 313.

tion was 513 bbl. of 36° A.P.I. oil per day through a $\frac{5}{16}$-in. choke with tubing pressure of 2700 lb. and casing pressure of 3400 lb. Because of salt-water intrusion this well was later plugged back and is producing a small amount of distillate at 10,530 feet.

Long Lake.—Fohs Oil Co. and Pilgrim Exploration Co. discovered Miocene production in their State Long Lake No. 1, sec. 65, 17 S., 19 E., Lafourche Parish. Initial production was 890 bbl. of 38° A.P.I. oil per day through a $\frac{1}{4}$-in. choke with tubing and casing pressure of 1400 lb. Oil sands were found from 9365 to 9373 ft., the total depth.

Venice.—Exploration on the flank of the Venice salt dome resulted in the sixth discovery for the year. Tidewater Associated Oil Company's Manhattan Fruit Co. No. 3, sec. 26, 21 S., 30 E., Plaquemines Parish, found saturation in Miocene sands from 7180 to 7208 ft. The discovery well made 216 bbl. of 39° A.P.I. gravity oil per day through a $\frac{5}{32}$-in. choke with tubing pressure of 900 pounds.

TABLE 1.—(*Continued*)

Line Number	Total Oil Production, Bbl.			Total Gas Production, Millions Cu. Ft.				Number of Oil and/or Gas Wells							
	During 1936	During 1937	Daily Average during Nov. 1937	To End of 1937	During 1936	During 1937	Maximum Daily during 1937	Completed to End of 1937	During 1937		At End of 1937				
									Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Oil and Gas[b]	Producing Gas Only	Total Producing
1	806,446	2,974,847	14,394					574	47	0	0	95			95
2	19,700	68,391	277					38	3	0	0	7			7
3	11,962	10,360	28					67	0	0	3	14			14
4	652,347	474,974	1,238					444	3	1	9	72			72
5	69,081	60,940	150					177	0	0	5	13			13
6	0	0	0					4	0	0	0				
7	0			14,295				10	0	0	0				
8	11,589	750	0					11	0	0	1				
9	1,773,125	6,150,391	14,865					42	17	0	1	37			37
10	473,422	516,007	1,337					83	1	0	8	26			26
11	183,184	220,350	677					30	1	0	2	20			20
12	1,760,376	1,418,793	3,073					111	15	3	12	69			69
13	351,984	292,142	721					9	0	0	1	5			5
14	0	1,111	0					5	1	0	1				
15	189,620	1,378,827	3,627					83	25	1	7	40			40
16	2,969,047	3,250,010	8,687					126	5	0	8	51			51
17	139,071	69,141	160					12	0	0	5	2			2
18	332,588	494,049	1,538					10	1	0	2	8			8
19	836,411	618,931	1,297					46	0	0	6	26			26
20	229,308	627,876	2,487					26	3	0	2	3			3
21	0	1,702	0					7	1	0	1				
22	1,086,952	1,304,343	3,498					28	2	0	6	17			17
23	60,903	315,068	1,248					8	4	0	2	4			4
24	2,534,433	1,367,859	2,503					43	2	0	3	24			24
25	5,519,712	6,405,683	15,469					37	11	0	0	35			35
26	1,829,798	1,484,703	3,586					36	2	0	5	29			29
27	351,516	441,449	980					12	2	0	1	8			8
28	432,009	437,867	909					16	0	0	6	7			7

TABLE 1.—(*Continued*)

	Depth, Average in Feet		Oil Production Methods at End of 1937					Character of Oil, Approx. Average during 1937					Character of Gas, Approx. Average during 1937	
			Number of Wells					Gravity A.P.I. at 60°F.						
Line Number	Bottoms of Productive Wells	To Top of Productive Zone	Flowing	Pumping	Gas-lift	Air-lift	Injection into Reservoir[c]	Maximum	Minimum	Weighted Average	Sulphur, Per Cent	Base[e]	B.t.u. per Cu. Ft.	Gal. Gasoline per M Cu. Ft.
1	1,944	1,833[1]	35	60				26–34.5	21–34.5	28	0.17	A		
2	1,506	1,351[2]	2	5				24	22	23	0.37	A		
3	1,158	1,148		14				22.6	22	22.3	0.15	A		
4	2,752	2,685[3]		71		1		32	20	29.4	0.30	A		
5	3,145	3,107[4]	3	10				22	19	20	0.18	A		
6	1,269	1,200												
7	2,469	2,448												
8	3,050	2,835[5]												
9	2,458	2,398[6]	36	1				24.9	24.9	24.9	0.26	A		
10	4,558	4,533[7]	14	12				41	23	33	0.12	A		
11	2,272	2,224[8]	3	17				32	18	25	0.30	A		
12	4,160	4,136[9]	49	12		8		36	19	26	0.31	A		
13	6,284	6,262[10]	4	1				32	29	28.5	0.12	A		
14	6,430 1,170	6,384 1,137												
15	3,331	3,296[11]	16	24				32	19	20	0.37	A		
16	3,700	3,668[12]	21	30				32	20	28	0.44	A		
17	1,639 4,351	1,624 4,338		2				31	26	28	0.38	A		
18	5,188 5,836	5,170[13] 5,700	4	1	3			26.5	24.2	25	0.36	A		
19	3,407	3,368[14]		26				33.7	25	27	0.33	A		
20	1,068 7,125	1,056 7,101[15]	3					38.5	38.5	38.5	0.22	A		
21	2,319	2,262[16]												
22	4,535	4,446[17]	7	4	6			23.8	18	21	0.11	A		
23	1,373 6,270	1,274 6,248[18]	4					34.3	34.3	34.3	0.55	A		
24	3,836	3,777[19]	16	8				35.5	33	34	0.32	A		
25	4,555	4,510[20]	35					34	32	33	0.26	A		
26	4,113	4,080[21]	14	15				41	27	37	1.0	A		
27	3,107	3,052[22]	2	6				29.6	26.4	28.2	0.15	A		
28	1,154	1,135	7					19	18	18.3	0.73	A		

[1] Production obtained from following zones: 1515–2075 ft.; 3915–4330 ft.; 5480–5530 ft.; 6360–6900 ft.; 6100–7100 ft.; 6760–6910 ft.; 7300–7392 ft.; 7525–7545 ft.; 7683–7803 ft.; and 8600–8760 ft.

[2] Production obtained from following zones: 400–760 ft.; 1380–1535 ft.; and 1645–1890 ft.

[3] Production obtained from following zones: 1100–1170 ft.; 1510–2150 ft.; 2050–2440 ft.; 2600–2800 ft.; 2915–3272 ft.; and 3395–3665 ft.

[4] Production obtained from following horizons: 1060–1558 ft.; 2314–2355 ft.; 2655–2795 ft.; 2890–2920 ft.; 3095–3205 ft.; 3100–3264 ft.; 3405–3650 ft.; 3680–3740 ft.; 3910–4055 ft.

[5] Production obtained from following horizons: 410–450 ft.; 3025–3210 ft.; 3235–3360 ft.; and 4284–4341 ft.

[6] Producing zones: 1008–1070 ft.; 1665–1701 ft.; 2690–2855 ft.; 3805–3828 ft.; 4010–4050 ft.; 4476–4500 ft.; 4592 ft.; 4650–4794 ft.; 4812–4888 ft.; 5385–5410 ft.

[7] Producing zones: 1000–1095 ft.; 2960–3237; 3385–3400; 3620–3875; 4315–4435; 4705–4924; 5100–5665; 5970–5985; and 6445–6623 ft.; 6687–6737; and 6917–6937 ft.

[8] Producing zones: 535–570 ft.; 746–910; 1205–1240 C.R.; 1080–1278 Sd.; 2300–2315 ft.; 3000–3020; 3400–3420: 3690–3721; 4175–4288; 4436–4481; 4759–4795 ft.

[9] Producing zones: 2760–2950; 3150–3575; 3985–4200; 4300–4525; 4775–5175; 5496–5512; and 5325–5700 ft.

[10] Producing zones: 5170–5195; 5632–5718; 5900–5925; 6795–6815; and 7335–7387 ft.

[11] Producing zones: 3010–3400; 3700–3975; 4275–4350; and 5850–5870 ft.

[12] Producing zones: 2610–3100; 3900–4015; 5990–6140; 7232–7242; 7370–7390; 7480–7525; and 7630–7675 ft.

[13] Producing zones: 5170–5188; 5700–6042; 6440–6559; 8894–8902; and 8925–8942 ft.

[14] Producing zones: 3150–3200; 3320–3420; 3542–3568; and 3710–3717; 4867–4883 ft.

[15] Producing zones: 1056–1068; 6830–6877; 7101–7125 ft.

[16] Producing zones: 1710–1735; 1900–2300; and 3575–3590 ft.

[17] Producing zones: 965–980; 4380–4520; 5080–5220; and 6615–6630 ft.

[18] Producing zones: 1274–1373; 5420–5465; 6248–6270; and 6440–6540 ft.

[19] Production from sands between 3650 and 4080 ft.

[20] Producing zones: 3206–3243; 3765–4006; 5062–5097; 4327–4383; 4871–4913; 6620–6648; and 6829–6842 ft.

[21] Producing zones: 3310–3375; 3510–3580; 3770–3850; 3904–4100; 4243–4259; 4325–4410; and 5263–5273 ft.

[22] Producing zones: 2030–2050; 2410–2560; 2880–2900; 4100–4400; 4515–4581; and 5413–5473 ft.

Bayou des Allemands.—The discovery well and the first drilled in this area was Amerada Petroleum Corporation's and Louisiana Land and Exploration Company's State No. 1, sec. 13, 15 S., 20 E., St. Charles Parish. It was completed in Miocene sand at 6820 to 6830 ft. after encountering salt at 8632 ft. Initial production was 570 bbl. of 34° A.P.I. oil per day through an $^{18}/_{64}$-in. choke with casing and tubing pressure 950 and 400 lb., respectively.

Horseshoe Bayou.—The second deepest producing field in the world was discovered by The Texas Company's Horseshoe Bayou No. 1, sec. 40, 17 S., 19 E., St. Mary Parish. The initial production was 1150 bbl.

TABLE 1.—(*Continued*)

Line Number	Producing Rock						Number of Dry and/or Near-dry Holes to End of 1937	Deepest Zone Tested to End of 1937	
	Name	Age[f]	Character[g]	Porosity[h]	Net Thickness, Average in Feet	Structure[i]		Name	Depth of Hole, Ft.
1	"Fleming," Marginulina	Mio	S	Por	120	DS	116	Vicksburg	3,856, 8,903
2	Citronelle, "Fleming," Jackson	Pli, Mio, Eoc	S	Por	35	DS	83	Jackson	1,500[30]
3	Pli-Mio contact	Pli, Mio	S	Por	8	D	43	Vicksburg	9,010
4	PliL, "Fleming," Discorbis, Marginulina	Pli, Mio	S	Por	90	DS	207	Jackson	6,939
5	PliL	Pli	S	Por	130	DS	90	Jackson	8,414
6	"Fleming"	Mio	S	Por	30	DS	34	"Fleming"	5,112
7	Upper Marine Mio	Mio	S	Por	10	D	13	Mio	5,645
8	"Fleming"	Mio	S	Por	28	DS	43	Vicksburg	3,910[31]
6	PliL, "Fleming"	Pli, Mio	S	Por	46	DS	50	MioL	7,934
10	"Fleming," Heterostegina	Mio	S	Por	100	D	18	Marginulina	7,902
11	PliL, cap rock, "Fleming," MioL	Pli, Mio	S	Por	40	DS	60	Jackson[32]	7,207
12	"Fleming," Heterostegina	Mio	S	Por	120	DS	42	Mio	9,250[33]
13	"Fleming"	Mio	S	Por	40	DS	7	Mio	8,070
14	"Fleming"	Mio	S	Por	7	DS	19	"Fleming"	7,157
15	"Fleming"	Mio	S	Por	35	DS	118	Jackson	3,424[34]
16	"Fleming"	Mio	S	Por	65	DS	75	Claiborne	6,963[35]
17	Cap rock, Vicksburg	x, Olig	A, S	Por	45	DS	29	Vicksburg	5,725[36]
18	"Fleming"	Mio	S	Por	30	DS	6	"Fleming"	9,127
19	Marginulina	Mio	S	Por	35	DS	31	Heterostegina	7,213
20	PliL	Pli	S	Por	12	DS	15	MioU	7,128
21	"Fleming"	Mio	S	Por	20	DS	15	"Fleming"	6,103
22	Cap rock, MioU, Heterostegina?	x, Mio	L, S	Por	120	DS	26[37]	Marginulina?	6,200[38]
23	Upper Marine Mio	Mio	S	Por	55	DS	9	MioU	7,039
24	Upper Marine Mio	Mio	S	Por	75	DS	16	MioU	10,959
25	Upper Marine Mio	Mio	S	Por	90	DS	17	MioU	6,648
26	"Fleming"	Mio	S	Por	40	DS	10	MioU	9,331
27	"Fleming"	Mio	S	Por	40	DS	18[39]	"Fleming"	8,969
28	Cap rock, Super-cap sand	x, Pli	L, S	Por	26	DS	30	Mio	5,860[40]

[30] Deepest well abandoned at 6204 ft. in the Miocene.
[31] Deepest well abandoned at 6471 ft. in lower Miocene.
[32] Abandoned in heaving shale.
[33] Abandoned in salt.
[34] Deepest well abandoned at 7834 ft.
[35] Deepest well abandoned at 8384 ft.
[36] Deepest well abandoned at 6565 ft.
[37] Includes seven sulphur tests.
[38] Deepest test abandoned at 6905 ft.
[39] Includes eight sulphur tests.
[40] Abandoned in salt at 6179 ft.

of 40° A.P.I. oil per day through a ¼-in. choke with tubing pressure of 2000 lb. The well was plugged back from 12,261 ft. and brought in through perforations in Miocene sand from 10,863 to 10,873 feet.

South Elton.—Another 1937 discovery was Stanolind Oil and Gas Company's Calcasieu National Bank 2-B, Jefferson Davis Parish. The discovery well is in sec. 28, 7 S., 3 W., and was completed through casing perforations from 8955 to 8965 ft. in the Chickisawhay after plugging back from 9339 ft. in the Vicksburg. Initial production was 128 bbl. of 52° A.P.I. distillate and four million cubic feet of gas per day through a ¼-in. choke with tubing pressure of 3000 pounds.

North Crowley.—The second discovery for the Humble Oil and Refining Co. was North Crowley, Acadia Parish. Federal Land Bank No. 1,

TABLE 1.—(*Continued*)

Line Number	Field, *Parish*	Age, Years to End of 1937	Area Proved, Acres				Total Oil Production, Bbl.
			Oil	Oil and Gas[a]	Gas	Total	To End of 1937
29	Leeville, *Lafourche*	7	210	0	0	210	17,124,468
30	Iowa, *Calcasieu, Jefferson-Davis*	7	0	1,000		1,000	29,405,527
31	Darrow, *Ascension*	6	130	0	0	130	1,522,845
32	Gueydan, *Vermillion*	6	50	0	0	50	732,911
33	Bosco, *Acadia-St. Landry*	4	1,250	0	0	1,250	15,028,716
34	Lake Hermitage, *Plaquemines*	4	25	0	0	25	109,434
35	Roanoke, *Jefferson-Davis*	4	500	0	0	500	6,075,672
36	Four Isle, *Terrebonne*	4	20	0	0	20	92,870
37	Gillis, *Calcasieu*	4	400	0	0	400	12,909,796
38	Lafitte, *Jefferson*	3	0	600	0	600	7,507,509
39	Tepetate, *Acadia*	3	0	1,200	0	1,200	4,006,324
40	Bunkie, *Rapides*	3	0	50	0	50	271,986
41	St. Martinsville, *St. Martin*	3	0	50	0	50	543,039
42	Jeanerette, *St. Mary*	3	250	0	0	250	3,268,754
43	Garden Island Bay, *Plaquemines*	3	50	0	0	50	969,401
44	Charenton, *Lafourche*	2	100	0	0	100	250,918
45	Big Lake, *Cameron*	2	20	0	0	20	40,419
46	Bayou Mallet, *Acadia*	2	60	0	10	70	119,676
47	Valentine, *Lafourche*	2	200	0	0	200	970,066
48	Cankton, *St. Landry*	2	50	0	0	50	12,249
49	South Jennings, *Jefferson-Davis*	2	60	0	0	60	2,771
50	Bay St. Elaine, *Terrebonne*	1	80	0	0	80	51,453
51	Abbeville, *Vermillion*	1	40	0	0	40	11,386
52	Venice, *Plaquemines*	1	20	0	0	20	159,206
53	South Elton, *Jefferson-Davis*	1	40	0	0	40	1,999
54	South Roanoke, *Jefferson-Davis*	1	40	0	0	40	4,130
55	Lake Long, *Lafourche*	1	60	0	0	60	83,614
56	Gibson, *Terrebonne*	1	80	0	0	80	418,643
57	Potash, *Plaquemines*	1	10	0	0	10	30
58	Bayou des Allemands, *St. Charles*	1	40	0	0	40	37,295
59	Horseshoe Bayou, *St. Mary*	1	40	0	0	40	74,671
60	North Crowley, *Acadia*	1	100	0	0	100	31,150
61	Ville Platte, *Evangeline*	1	300	0	0	300	2,391
62	Quarantine Bay, *Plaquemines*	1	40	0	0	40	971
63	Bateman Lake, *St. Mary*	1	40	0	0	40	2,408
64	Lirette, *Terrebonne*	1	20	0	0	20	26,342
65	Total		7,425	2,900	730	11,055	329,647,286

sec. 34, 8 S., 1 E., after testing sands in the Frio at 9339 ft. was plugged back to the Heterostegina zone and completed in sand at 8082 to 8102 ft. It tested 680 bbl. of 36° A.P.I. oil per day through a ¼-in. choke with tubing and casing pressure of 1175 pounds.

Ville Platte.—The first well in this area to find production in the Sparta sand was Continental Oil Company's Tate No. 1, sec. 44, 3 S., 9 E., Evangeline Parish, completed in sand at 9007 to 9035 ft. Production from this horizon opens up many prospects for deep drilling along the "Conroe Trend" which have proved dry in the Cockfield sand section. Initial production was 172 bbl. of 55° A.P.I. oil and two million cubic feet of gas daily through a 3⁄16-in. choke with a tubing pressure of 2500 lb. and casing pressure of 2700.

TABLE 1.—(*Continued*)

Line Number	Total Oil Production, Bbl.			Total Gas Production, Millions Cu. Ft.				Number of Oil and/or Gas Wells							
									During 1937		At End of 1937				
	During 1936	During 1937	Daily Average during Nov. 1937	To End of 1937	During 1936	During 1937	Maximum Daily during 1937	Completed to End of 1937	Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Oil and Gas[b]	Producing Gas Only	Total Producing
29	4,596,027	2,651,187	5,917					123	14	0	11	97			97
30	6,568,936	6,335,933	17,089	13,960.5	4,556	4,627.5	y	80	10	0	10	46	46		46
31	525,997	716,022	1,878					13	4	0	2	8			8
32	60,026	100,877	382					6	1	0	1	5			5
33	4,577,615	3,017,508	7,399	11,546.9	4,820	6,726.9	y	69	0	0	14	57		5	62
34	22,964	15,212	51					3	0	0	0	3			3
35	2,260,365	1,957,009	4,872					35	8	0	4	30			30
36	11,018	2,418	4					2	0	0	1	1			1
37	5,678,922	5,087,762	10,559	y		y	y	70	13	0	3	65			65
38	2,724,454	4,138,111	11,056	4,020.5	0	4,020.5	y	17	9	0	1	0	18		18
39	1,472,885	2,401,675	5,459	11,118.5	0	11,118.5	y	54	14	0	0	0	53		53
40	165,155	97,912	182	3,524.1	1,825	1,588.1	y	5	0	0	0	0	5		5
41	301,335	213,352	754	136.8	53	63.8	y	4	1	0	1	0	2		2
42	993,522	2,272,418	6,909					22	11	0	0	22			22
43	310,884	606,212	2,204					8	4	0	2	6			6
44	16,709	234,272	872					5	4	0	0	5			5
45	1,853	38,556	140					3	2	0	1	2			2
46	55,431	64,245	13					5	1	0	1	4			4
47	0	970,066	4,933					14	14	0	0	13			13
48	0	12,249	31					2	2	0	0	2			2
49	0	2,771	6					1	1	0	0	1			1
50		51,453	269					3	1	0	0	1			1
51		11,386	0					2	2	0	0	2			2
52		159,206	1,050					2	2	0	0	1			1
53		1,999	4					1	1	0	0	1			1
54		4,130	49					2	2	0	0	1			1
55		83,614	367					1	1	0	0	1			1
56		418,043	2,604					5	5	0	0	5			5
57		30	1					1	1	0	0	1			1
58		37,295	315					1	1	0	0	1			1
59		74,671	455					1	1	0	0	1			1
60		31,150	y					2	2	0	0	2			2
61		2,391	0					1	1	0	0	1			1
62		971	32					1	1	0	0	1			1
63		2,408	0					1	1	0	0	1			1
64		26,342	23					1	1	0	0	1			1
65	51,968,727	62,147,690	168,628	58,620.3	11,254	28,720.3		2,706	282	5	150	954	124	5	1,083

Potash.—The third discovery for Humble Oil and Refining Co. was on the Potash prospect in Plaquemines Parish. The discovery well, Orleans Levee Board No. 11, sec. 10, 8 S., 15 E., was completed flowing 25 bbl. of 25° A.P.I. oil per day from super-cap sands found at 689 to 695 ft.

TABLE 1.—(*Continued*)

	Depth, Average in Feet		Oil Production Methods at End of 1937					Character of Oil, Approx. Average during 1937					Character of Gas, Approx. Average during 1937	
			Number of Wells					Gravity A.P.I. at 60°F.						
Line Number	Bottoms of Productive Wells	To Top of Productive Zone	Flowing	Pumping	Gas-lift	Air-lift	Injection into Reservoir[c]	Maximum	Minimum	Weighted Average	Sulphur, Per Cent	Base[e]	B.t.u. per Cu. Ft.	Gal. Gasoline per M Cu. Ft.
29	3,729	3,660[23]	17	74	4	2		29.2	22.9	26	0.40	A		
30	6,941	6,920[24]	46					49.7	25.4	41	0.37	M	1,102	0.50
31	[25]	[25]	7	1				41.6	34.1	37	0.12	A		
32	3,972	3,924[26]	3	2				27.5	27.1	27.3	0.12	A		
33	[27]	[27]	40		22			45.6	36	38.5	0.17	M		
34	[28]	[28]		3				32.1	32.1	32.1	0.06	A		
35	8,477	8,454[29]	26	1	3			38.4	37	38	0.10	M		
36	5,642	5,512	1					44.5	44.3	44.4	0.18	M		
37	[41]	[41]	52		13		2g	34.1	34.1	34.1	0.68	A	*y*	*y*
38	[42]	[42]	18					35	35	35	0.19	A		
39	8,315	8,275	53					44.5	31	37	0.34	M		
40	5,710	5,704	5					53.9	53.9	53.9	0.30	A	1,146	0.75
41	5,582	5,557	2					32	32	32	0.21	A	1,019	0.03
42	[43]	[43]	21	1				40.7	40.7	40.7	0.31	M		
43	[44]	[44]	5	1				37.2	37.2	37.2	0.25	A		
44	7,185[45]	7,206[45]	5					36	35.5	36	0.42	M		
45	8,334 7,944	8,318[46] 7,966	2					55	55	55	*y*	P	*y*	Wet
46	6,385	6,390	4					36.7	27.9	30	0.22	M	*y*	Wet
47	6,950	5,370[47]	13					35	31	32	0.30	M		
48	5,323	5,315	2					52	52	52	*y*	P		
49	8,648	8,634	1					50	50	50	*y*	P		
50	5,643	5,520	1					30	30	30	*y*	M		
51	7,682 7,890	7,668 7,884	2					42	41	41.5	*y*	P		
52	7,208	7,180	1					40	38	39	0.10	P		
53	8,965	8,955	1					54	54	54	*y*	P		
54	8,563	8,540	1					50	50	50	*y*	P		
55	9,375	9,365	1					38	38	38	0.12	P		
56	9,490	9,460	5					38	38	38	*y*	P		
57	695	689		1				25	25	25	*y*	A		
58	6,830	6,820	1					34	34	34	0.11	P		
59	10,873	10,863	1					40	40	40	*y*	P		
60	8,102	8,082	2					36	36	36	0.17	P		
61	9,035	9,007	1					55	55	55	*y*	P		
62	8,177	8,134	1					36	36	36	*y*	P		
63	10,905	10,900	1					33	33	33	*y*	M		
64	10,530 11,630	10,517 11,620	1					50	36	45	0.34	P		
65			618	403	51	11								

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[23] Oil and/or gas produced from sands found at the following depths: 2800–3000; 3300–3560; 3670, 3760, 3837, 4200, 4400, and 4980–5047 ft.

[24] Production obtained from sands found at the following average depths: 4426, 4515, 5135, 5585, 6525, 6935. Most wells have been deepened to or completed in the zone of 6935 ft.

[25] Producing zones: 4008–4035; 4820–4827; 5488–5513; 5669–5686; 5882–5836; and 6485–7000 ft.

[26] Producing zones: 3450–3555; 3890–4300; and 4820–4850 ft.

[27] Producing zones: 7760–7830; 8050–8090; 8420–8500; 8620–8700; 8750–8800; 9004–9024; and 9018–9028 ft.

[28] Producing zones: 3176–3191; 4257–4269; and 4640–4646 ft.

[29] Producing zones: 7796–7918; 8660–8682; 8814–8830; and 9314–9345 ft.

[41] Producing zones: 5156–5180; 5258–5272: 6413–6419; 6710–6767; 7005–7085; 7368–7377; and 9242–9246 ft.

[42] Producing zones: 9396–9440; 9555–9575; 9912–9968; and 10030–10110 ft.

[43] Producing zones: 6630–6660; 6725–6735; 7010–7055; 7478–7498; 10272–10292; and 10412–10424 ft.

[44] Producing zones: 4450–4480; 4601–4616; 4885–4895; and 4915–4930 ft.

[45] Producing zones: 3940–3948; 4955–4980; 7185–7206; and 7908–7923 ft.

[46] Producing zones: 7944–7966; 8318–8334; and 9040–9060 ft.

[47] Producing zones: 5050–5085; 5370–5390; 5407–5422; 5500–5515; and 6082–6150 ft.

Earlier in the year, the Humble Oil and Refining Co. and Texas Gulf Sulphur Co. proved the Potash dome when their Orleans Levee Board No. 1 was completed in salt at 1468 feet.

Quarantine Bay.—In November the Quarantine Bay prospect, Plaquemines Parish, was converted into an oil field. Gulf Oil Corporation's State QQ-3, sec. 17, 19 S., 17 E., came in flowing 845 bbl. of 36° A.P.I. oil daily through a ¼-in. choke with a tubing pressure of 1375 lb. and casing pressure of 1100 lb., from Upper Miocene sand at 8134 to 8177 feet.

Bateman Lake.—The fourteenth field for the year, and one of the most important discoveries, was on the Bateman Lake prospect in St. Mary Parish. The Texas Company's Bateman Lake No. 1., sec. 21, 16 S.,

TABLE 1.—(*Continued*)

Line Number	Producing Rock						Number of Dry and/or Near-dry Holes to End of 1937	Deepest Zone Tested to End of 1937	
	Name	Age[f]	Character[g]	Porosity[h]	Net Thickness, Average in Feet	Structure[i]		Name	Depth of Hole, Ft.
29	Upper Marine Mio	Mio	S	Por	120	DS	23	MioU	7,300[33]
30	"Fleming," Heterostegina, Marginulina	Mio	S	Por	53	D	10	Vicksburg	9,161
31	Upper Marine Mio	Mio	S	Por	34	DS	20	MioU	7,894
32	"Fleming"	Mio	S	Por	31	DS	11	Discorbis	9,545
33	Discorbis, Heterostegina, Marginulina	Mio	S	Por	90	D	11	Vicksburg?	10,005
34	Upper Marine Mio	Mio	S	Por	15	DS	16	MioU	9,770
35	Heterostegina, Marginulina	Mio	S	Por	150	D	52	Marginulina	10,750
36	Upper Marine Mio	Mio	S	Por	50	DS	13	MioU	9,526
37	Marginulina	Mio	S	Por	15	D	21	Marginulina	9,246
38	Miocene	Mio	S	Por	45	D	0	Miocene	12,128
39	Marginulina	Mio	S	Por	35	D	10	Vicksburg	9,000
40	Cockfield	Eoc	S	Por	10	D	0	Cook Mountain	6,838
41	Shoal River	Mio	S	Por	25	D	8	Miocene	9,648
42	Upper Marine Mio	Mio	S	Por	20	D	7	Miocene	11,634
43	Upper Marine Mio	Mio	S	Por	15	DS	12	Miocene	5,651
44	Miocene	Mio	S	Por	10	D	5	Miocene	8,822
45	Lower Miocene	Mio	S	Por	20	D	1	Heterostegina	9,501
46	Heterostegina	Mio	S	Por	20	D	3	Frio	8,404
47	Upper Miocene	Mio	S	Por	30	D	5	Vicksburg	7,236
48	Upper Miocene	Mio	S	Por	10	D	2	Frio	9,428
49	Upper Miocene	Mio	S	Por	20	D	2	Heterostegina	9,180
50	Upper Miocene	Mio	S	Por	60	DS	14	Miocene	5,643
51	Upper Miocene	Mio	S	Por	20	D	0	Alazan?	11,909
52	Upper Miocene	Mio	S	Por	30	DS	6	Miocene	7,300
53	Alazan	MioL	S	Por	25	D	1	Vicksburg	10,181Dr.
54	Upper Miocene	Mio	S	Por	25	D	0	Marginulina	9,749
55	Upper Miocene	Mio	S	Por	35	D	0	Miocene	9,373
56	Upper Miocene	Mio	S	Por	40	D	1	Miocene	10,727
57	Super-cap sand	Pli	S	Por	10	DS	18	Miocene	1,575
58	Upper Miocene	Mio	S	Por	15	DS	0	Miocene	8,632
59	Upper Miocene	Mio	S	Por	15	D	0	Miocene	12,261
60	Heterostegina	MioL	S	Por	25	D	1	Frio	9,339
61	Sparta	Eoc	S	Por	40	D	0	Sparta	9,035
62	Upper Miocene	Mio	S	Por	45	D	0	Miocene	8,177
63	Upper Miocene	Mio	S	Por	10	D	0	Miocene	11,879
64	Upper Miocene	Mio	S	Por	10	D	0	Miocene	12,165
65							1,513		

12 E., was plugged back from 11,879 ft. and completed through perforations in Miocene sand at 10,900 to 10,905 ft. The initial production was 350 bbl. of 33° A.P.I. oil daily through a 3⁄16-in. choke with tubing pressure of 850 pounds.

OTHER DEVELOPMENTS

The first oil producer for the Big Lake gas field was Union Sulphur Company's Hebert No. 1, sec. 18, 12 S., 8 W., Cameron Parish. Completed in the upper Miocene at 8318 to 8334 ft., the initial production was 700 bbl. of 39° A.P.I. oil per day through a ¼-in. choke with tubing pressure of 1250 pounds.

Of the 16 wells drilled at Bay St. Elaine, two were completed in super-cap sands as gas producers. Because of the high sulphur content and high pressures encountered across the crest of the dome, exploration has been confined to discovery of flank production. The first producer, The Texas Company's State Bay St. Elaine No. 14, sec. 20, 22 S., 18 E.,

TABLE 2.—*Summary of Drilling Operations in South Louisiana*

Important Wildcats Drilled in 1937

	Parish, Field	Location			Total Depth, Ft.	Surface Formation
		Sec.	Twp.	Rge.		
1	*Acadia,* Jennings	41	9 S	2 W	6,520	Recent
2	*Terrebonne,* L. Pelto	17	23 S	18 E	7,160	Recent
3	*Jefferson,* Lafitte	20	17 S	4 E	10,942	Recent
4	*Terrebonne,* Caillou Is.	18	23 S	29 E	5,097	Recent
5	*Iberia,* New Iberia	54	12 S	7 E	5,034	Recent
6	*Iberia,* Fausse Point	35	11 S	8 E	7,157	Recent
7	*Calcasieu,* Sulphur	9	9 S	10 W	5,512	Recent
8	*Terrebonne,* Dog Lake	5	22 S	16 E	6,894	Recent
9	*Terrebonne,* Caillou Is.	18	23 S	20 E	4,910	Recent
10	*Lafourche,* Valentine	8	17 S	20 E	5,390	Recent
11	*Lafourche,* Valentine	8	17 S	20 E	7,190	Recent
12	*Acadia,* Jennings	42	9 S	2 W	8,329	Recent
13	*Terrebonne,* Caillou Is.	18	23 S	20 E	4,537	Recent
14	*St. Mary,* Charenton	30	13 S	10 E	7,923	Recent
15	*Terrebonne,* Caillou Is.	19	23 S	20 E	6,648	Recent
16	*Cameron,* Big Lake	18	12 S	8 W	8,336	Recent
17	*Ascension,* Darrow	34	10 S	2 E	6,995	Recent
18	*Lafourche,* Valentine	8	17 S	20 E	5,515	Recent
19	*St. Mary,* Charenton	30	13 S	10 E	7,923	Recent
20	*Calcasieu,* Lockport	9	10 S	9 W	6,937	Recent
21	*Cameron,* E. Hockberry	12	12 S	9 W	7,678	Recent
22	*Terrebonne,* Dog Lake	5	22 S	16 E	6,868	Recent
23	*Lafourche,* Valentine	8	17 S	20 E	5,075	Recent
24	*Lafourche,* Valentine	8	17 S	20 E	6,960	Recent
25	*Terrebonne,* Lake Pelto	17	23 S	18 E	6,594	Recent
26	*St. Mary,* Charenton	30	13 S	10 E	6,305	Recent
27	*Cameron,* Big Lake	18	12 S	8 W	9,060	Recent
28	*St. Mary,* Jeanerette	40	13 S	9 E	10,480	Recent
29	*Jeff. Davis,* S. Roanoke	23	10 S	4 W	9,151	Recent
30	*Terrebonne,* Livette	32	19 S	19 E	12,165	Recent
31	*Vermilion,* Abbeville	66	12 S	3 E	11,909	Recent
32	*St. Mary,* Jeanerette	40	13 S	9 E	10,480	Recent
33	*Terrebonne,* Lake Pelto	17	23 S	18 E	6,605	Roentt

Terrebonne Parish, flowed 1000 bbl. of 30° A.P.I. oil per day through a ⅜-in. choke with tubing pressure of 580 lb. Production is from broken Miocene sand found from 5520 to 5643 feet.

The first test in the Henderson area to encounter salt was The Texas Company's St. Martin Land Company No. 9, sec. 21, 8 S., 7 E., St. Martin Parish. The top of the salt was reported at 8848 feet.

The presence of a salt dome at the Marchland prospect was proved when William Helis' City of New Orleans No. 1, sec. 19, 23 S., 23 E., Lafourche Parish, was drilled into salt at 7465 ft.

The fifth salt dome discovered this year was on the Timbalier Bay prospect. Gulf Oil Corporation's State PP-3, sec. 36, 23 S., 21 E.,

TABLE 2.—(*Continued*)

Important Wildcats Drilled in 1937

	Deepest Horizon Tested	Drilled by and Farm	Initial Production per Day		Choke or Bean, Fractions of Inch	Pressure, Lb. per Sq. In.		Producing Depth
			Oil, U. S. Bbl.	Gas, Millions Cu. Ft.		Casing	Tubing	
1	Marginulina	Superior-Heywood No. 1	540		14/64	1,250	1,200	N.S. 6,460–6,520
2	Miocene	Texas-State No. 15	145		y		110	N.S. 5,420–5,465
3	Miocene	Texas-Milling No. 1	1,550		⅜		2,000	N.S. 10,030–10,110
4	Miocene	Texas-State No. 31	1,018		⅜		710	N.S. 5,062–5,097
5	Miocene	Texas-Hanazen No. B-3	900		⅜		650	N.S. 4,812–4,888
6	Miocene	Texas-State No. 2	55		⅜		0	N.S. 6,384–6,430
7	Lower Miocene	Sulphur-Fee No. 821	500		¼		760	N.S. 5,496–5,512
8	Miocene	Texas-Dog Lake No. 4	1,516		⅜		1,320	N.S. 6,870–6,877
9	Miocene	Texas State No. 46	1,156		y		625	N.S. 4,871–4,913
10	Miocene	Pan-Am.-Harange No. 2-A	624		5/32	770	720	N.S. 5,370–5,390
11	Miocene	Pan-Am.-Harange No. 4	625		3/16	820	785	N.S. 5,407–5,422
12	Salt	Superior-Leckelt No. 2	148		12/64	950	350	N.S. 5,780–5,790
13	Salt	Texas-State No. 47	235		y		990	N.S. 4,327–4,382
14	Miocene	Pan-Am.-S. Coast No. 1	625		¼	700	800	N.S. 7,908–7,923
15	Miocene	Texas-State Terrebonne No. 3	513		5/16		1,860	N.S. 6,620–6,648
16	Miocene	U. Sulphur-Hebert No. 1	700		¼		1,250	N.S. 8,318–8,334
17	Miocene	Humble-Landry No. 1	744		¼	1,375	1,290	N.S. 6,985–6,995
18	Miocene	Pan-Am.-Harange No. 5	641		¼	1,225	1,110	N.S. 5,515
19	Miocene	Pan-Am.-South Coast Corp. No. 1	384		3/16	1,155	1,100	N.S. 4,955–4,980
20	Marginulina	Magnolia-Wolf Friedburg No. 6	325		¼	1,225	400	N.S. 6,917–6,937
21	Miocene	Texas-State No. 22	700		¼		1,125	N.S. 7,630–7,677
22	Miocene	Texas-L.L.E. No. 5	1,480		⅜		1,150	N.S. 6,836–6,868
23	Miocene	Pan-Am.-Harange No. 7	514		28/64		y	N.S. 5,050–5,085
24	Miocene	Pan-Am.-Harange No. 9	432		¼	590	150	N.S. 6,082–6,150
25	Miocene	Texas-State No. 17	1,216		y		845	N.S. 6,440–6,475
26	Miocene	Pan Am.-Veder-Hunt No. 1	240		¼	50	275	N.S. 3,940–3,948
27	Basal Miocene	U. Sulphur-H. Hebert No. 1	100		¼		350	N.S. 9,040–9,060
28	Lower Miocene	Herton-Banta and Roanes No. 1	400		¼		3,200	N.S. 10,412–10,424
29	Marginulina	U. Sulphur-T.R.S. Farm No. 1	50	2.7	3/16		y	First oil well 8,560–8,563
30	Miocene	Humble-Ellender No. 1	21	1.8	¼	y	y	N.S. 10,517–10,530
31	Alazan	Continental-Brookshire No. 1	366		3/16	2,500	1,800	N.S. 7,884–7,890
32	Lower Miocene	Herton-Banta and Roans No. 1	180		3/16		3,200	N.S. 10,272–10,292
33	Miocene	Texas-State No. 13	910		⅜		670	N.S. 6,505–6,542

	In Proven Fields	Wildcats
Number of wells drilling Dec. 31, 1937	88	25
Number of oil wells completed during 1937	257	14
Number of gas wells completed during 1937	10	0
Number of dry holes completed during 1937	123	49

Lafourche Parish, encountered salt at 7741 ft. This well indicated it would open up a new field when two drill-stem tests showed commercial oil.

The Jennings field, Acadia Parish, was the most active area during the year. Prolific production has been developed on the southwest flank from sands of Marginulina age. This discovery has stimulated interest in the other shallow domes in that area.

New sands were found at Darrow, Ascension Parish; Valentine, Lafourche Parish; Charenton and Jeanerette, St. Mary Parish; Lockport and Sulphur, Calcasieu Parish; East Hackberry and West Hackberry, Cameron Parish; Dog Lake, Caillou Island, and Lake Pelto, Terrebonne Parish; Big Lake, Cameron Parish; Jennings, Acadia Parish; Lafitte, Jefferson Parish; New Iberia and Fausse Point, Iberia Parish; and Cankton, St. Landry Parish.

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Oil and Gas in Michigan during 1937

BY THERON WASSON,* MEMBER A.I.M.E.

(New York Meeting, February, 1938)

MICHIGAN produced 16,637,000 bbl. in 1937. This makes it a record year in the history of Michigan's oil industry. During the year 953 wells were completed; 779 within the limits of established fields and 174 wildcats; 616 new oil wells, 68 gas wells and 269 dry holes.

Table 1 has been arranged in alphabetical order of field names. Production figures for 1936 have been corrected because December figures were estimated. In this year's summary, December production is based on actual reports. The Leaton and Mt. Pleasant fields have been re-defined. Mt. Pleasant production north of the south line of Denver township, Isabella County, has been included with Leaton in accordance with usual practice in Michigan. The locations of fields discovered since the last map was published[1] are shown in Fig. 1.

ACTIVITY DURING 1937

Buckeye Field.—The Buckeye field of Gladwin County was the center of greatest activity during the year and was responsible for the increase of 4,700,000 bbl. over the state total for 1936. Buckeye produced 6,428,000 bbl. in 1937. In this field 328 producing wells were completed during the year—over one-half the oil producers drilled in the state. Buckeye was subject to voluntary and cooperative proration from April 1 to the end of the year. Other pools of the state were not prorated. The new production at Buckeye is from porous Dundee limestone of Devonian age, similar to the older fields.

Other New Fields.—The Sherman field was second in importance as a source of new production, with a total of 1,532,000 bbl. Salem township, Allegan County, on the southwest side of the Michigan Basin, was developed during the year. Production at Salem is from the Traverse limestone at a depth of 1600 ft., and 52 producing wells have been drilled in this pool. Other active pools were Clayton and Adams townships, Arenac County. The Bentley pool, discovered in October 1937 southeast of

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[1] *Trans.* A.I.M.E. (1936) **118**, 299.

Buckeye, has not had enough development to justify an opinion as to its size, but its location on a trend from Buckeye may indicate an area of production similar to that pool.

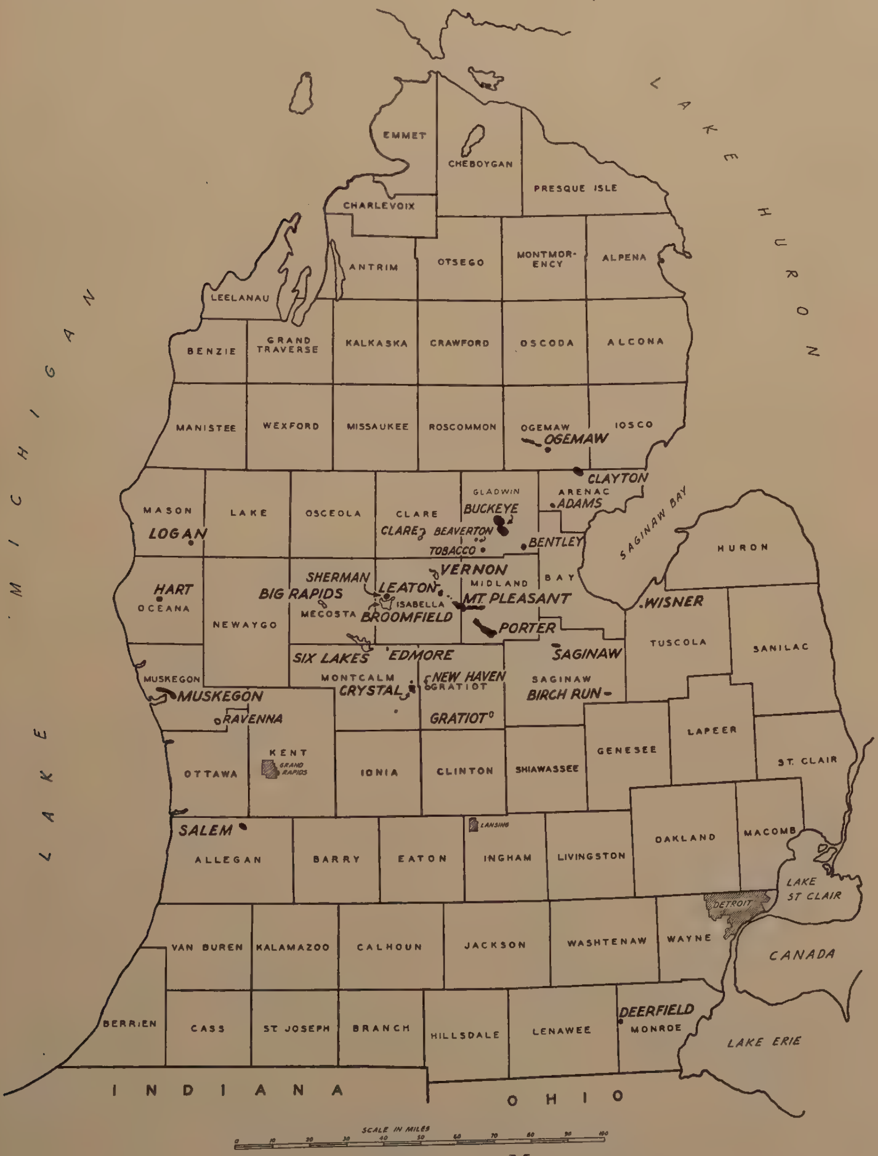

FIG. 1.—OIL FIELDS IN MICHIGAN.

Old Fields.—The old pools of Midland and Isabella Counties continued to produce from many pumping wells. The Yost-Porter area had some new development on inside locations. As shown by Tables 1 and 2, these old fields, now 6 to 10 years old, continue to produce remarkably well. The West Branch area of Ogemaw County continued active; 58 new producers were drilled. Oil is produced from the Traverse and Dundee, mostly the latter. It is black and of lower grade than that from other fields.

Gas Fields.—The Six Lakes field, which was completely outlined in 1936, is Michigan's greatest gas area. During the year, 20 new wells were drilled, bringing the total for the field to 226 producers. Two pipe-line systems gather and transport gas from this field to Saginaw, Bay City, Lansing and Grand Rapids.

Among the older gas areas, the Vernon field continued to produce and market considerable gas.

TABLE 1.—*Oil and Gas Production in Michigan*

Line Number	Field, *County*	Age, Years to End of 1937	Area Proved, Acres				Total Oil Production, Bbl.			
			Oil	Oil and Gas[a]	Gas	Total	To End of 1937	During 1936	During 1937	Daily Average during Nov. 1937
1	Adams, *Arenac*	½	400	0	0	400	13,414	0	13,414	110
2	Beaverton N. S., *Gladwin*	3	580	0	0	580	466,491	282,190	160,814	255
3	Bentley, *Gladwin*	½	2,500	0	0	2,500	7,339	0	7,339	55
4	Big Rapids, *Mecosta*	4½	0	0	2,200	2,200		0		0
5	Birch Run, *Saginaw*	3	300	0	0	300	136,122	63,548	36,315	55
6	Broomfield, *Isabella*	8	0	0	4,100	4,100		0		0
7	Buckeye, *Gladwin*	1½	6,030	0	0	6,030	6,438,774	10,475	6,428,299	25,073
8	Clare, *Clare*	8	0	0	320	320		0		0
9	Clayton, *Arenac*	1¼	3,400	0	0	3,400	1,088,132	58,465	1,029,667	2,368
10	Crystal, *Montcalm*	2½	1,980	200	200	2,380	6,630,977	2,452,906	572,807	966
11	Edmore, *Montcalm*	4	0	160	0	160	332,110	80,816	39,586	103
12	Gratiot, *Gratiot*	11	0	0	400	400		0		0
13	Hart, *Oceana*	5	0	0	0	0	116,275	0	0	0
14	Leaton, *Isabella*	8	2,100	0	480	2,580	2,234,323	356,746	287,804	708
15	Muskegon, *Muskegon*	10	0	2,700	0	2,700	6,508,195	92,629	77,466	216
16	Mt. Pleasant, *Midland-Isabella*	10	0	8,000	0	8,000	19,670,606	888,265	801,133	1,646
17	New Haven, *Gratiot*	2	0	0	2,400	2,400		0		0
18	Porter-Yost Clark, *Midland*	6	0	8,100	0	8,100	30,347,438	6,245,204	3,865,049	6,665
19	Ravenna, *Muskegon*	1½	0	0	4,320	4,320		0		0
20	Saginaw, *Saginaw*	13	1,800	0	0	1,800	1,273,333	27,146	24,810	61
21	Salem, *Allegan*	½	840	0	0	840	415,664	0	415,664	2,532
22	Sherman, *Isabella*	1¼	1,150	0	0	1,150	1,564,573	32,261	1,532,312	6,049
23	Six Lakes, *Mecosta-Montcalm*	3	0	0	10,120	10,120		0		0
24	Vernon, *Isabella*	8	1,100	0	880	1,980	3,533,838	468,804	396,590	793
25	West-Branch, *Ogemaw*	4	5,000	0	0	5,000	2,301,595	771,872	861,848	2,302
26	Miscellaneous,						215,056	103,541	86,427	
27	Total		27,180	19,160	25,420	71,760	83,294,255	11,934,868	16,637,344	49,957

[a] Footnotes to column heads and explanation of symbols are given on page 313.

The Ravenna field, Muskegon County, is unique in being the only gas field in Michigan producing from the Berea sandstone of Mississippian age. In this field, 21 new producers were drilled during 1937. No new gas fields of importance were discovered.

Exploration

Most of the exploration for new fields has been confined to shallow drilling for structural markers in areas where the glacial drift is from 200 to 700 ft. thick. Geophysical work done in the past has not been very successful in these drift-covered areas. During the year some gravimeter and resistivity surveys have been made. All the important wildcats drilled in 1937 were in the southern half of the basin. The northern half of the Michigan Basin remains practically unexplored. Deep drilling done during the year has not discovered new producing horizons.

Table 1.—(*Continued*)

Line Number	Total Gas Production, Millions Cu. Ft.				Number of Oil and/or Gas Wells								Depth, Average in Feet		Oil Production Methods at End of 1937		Pressure, Lb. per Sq. In.[d]		
						During 1937		At End of 1937							Number of Wells			Average at End of	
	To End of 1937	During 1936	During 1937	Maximum Daily during 1937	Completed to End of 1937	Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Oil and Gas[c]	Producing Gas Only	Total Producing	Bottoms of Productive Wells	To Top of Productive Zone	Flowing	Pumping	Initial	1936	1937
1	0	0	0	0	5	5	0	0	5	0	0	5	2,039	2,020	1	4	*x*	*x*	*x*
2	0	0	0	0	28	6	1	0	27	0	0	27	3,160	3,142	0	27	*x*	*x*	*x*
3	0	0	0	0	3	3	0	0	3	0	0	3	3,532	3,497	0	3	*x*	*x*	*x*
4	3,446	1,188	1,224	0.5	27	0	3	0	0	0	19	19	1,410	1,390	0	0	502	425	*y*
5	0	0	0	0	28	1	0	0	28	0	0	28	1,546	1,529	0	28	*x*	*x*	*x*
6	4,958	877	658	2.2	54	0	2	0	0	0	47	47	1,350	1,300	0	0	550	300	*y*
7	0	0	0	0	332	328	6	20	326	0	0	326	3,627	3,599	81e	245	*x*	*x*	*x*
8	12,642	241	243	1.4	9	2	0	0	0	0	9	9	1,413	1,408	0	0	605	400	*y*
9	0	0	0	0	40	38	2	7	31	0	0	31	2,576	2,534	0	31	*x*	*x*	*x*
10	291	143	43	0.2	239	22	64	1	78	0	9	87	O. 3,201 G. 1,021	O. 3,191 G. 1,016	0	78	G.448	G.425	*y*
11	36	8	12	0.3	13	0	0	0	8	0	4	12	G. 1,330 O. 3,112	G. 1,325 O. 3,108	0	8	900	*x*	*x*
12	4	0	0	0	3	0	0	3	0	0	0	0	510	500	0	0	*x*	*x*	*x*
13	0	0	0	0	17	0	0	0	0	0	0	0	1,890	1,880	0	0	*x*	*x*	*x*
14	131	57	61	0.34	90	7	12	0	64	0	4	68	G. 1,243 O. 3,681	G. 1,239 O. 3,644	0	64	550	*y*	G.395
15	6,569	263	174	0.79	411	0	18	0	91	10	11	112	2,075	2,050	0	91	*x*	*x*	*x*
16	2,032	671	504	1.6	440	11	23	0	100*y*	170*y*	0	270	3,573	3,542	0	270	*y*	*y*	*y*
17	691	179	512	2.4	47	12	0	0	0	0	47	47	975	950	0	0	448	425	*y*
18	2,862	911	144	2.6	513	30	25	0	353	73	0	426	3,434	3,422	0	426	*x*	*x*	*x*
19	477	41	436	1.6	27	21	0	0	0	0	27	27	1,233	1,212	0	0	720	682	*y*
20	0	0	0	0	282	0	10	0	55	0	0	55	1,850	1,820	0	55	*x*	*x*	*x*
21	0	0	0	0	52	52	0	0	52	0	0	52	1,601	1,587	*y*	*y*	*x*	*y*	*y*
22	0	0	0	0	64	61	8	0	52	0	1	53	3,652	3,648	0	52	*x*	*x*	*x*
23	7,011	2,167	4,538	19.6	242	20	5	*y*	0	0	226	226	1,300	1,275	0	0	515	475	*y*
24	1,133	124	143	0.79	91	3	9	0	44	0	10	54	G. 1,405 O. 3,744	G. 1,395 O. 3,741	0	44	575	310	*y*
25	0	0	0	0	252	58	17	*y*	213	0	0	213	T. 1,810 D. 2,707	T. 1,800 D. 2,622	0	213	*x*	*x*	*x*
26					21	2	0	0	20	0	0	20			0	20	*x*	*x*	*x*
27	42,283	6,870	8,692	34.3	3,330	682	205	31	1,550	253	414	2,217							

OIL PRICES

Oil prices were subject to some reductions during the year. In January 1937, Midland grade crude and Buckeye were $1.42 per barrel. At the end of the year Midland was priced at $1.27, Buckeye at $1.24½ and West Branch at $0.80.

ACKNOWLEDGMENTS

Mr. Carl C. Addison, Division Geologist, The Pure Oil Co., at Saginaw, Mich., and Mr. D. C. Shackelford, Chief Scout of the same company, assisted in the preparation of Tables 1 and 2. As in the past, the State Geological Survey of Michigan furnished production data on oil and gas and other information.

TABLE 1.—(*Continued*)

Line Number	Character of Oil, Approx. Average during 1937					Character of Gas, Approx. Average during 1937		Producing Rock						Number of Dry and/or Near-dry Holes to End of 1937	Deepest Zone Tested to End of 1937	
	Gravity A.P.I. at 60° F.															
	Maximum	Minimum	Weighted Average	Sulphur, Per Cent	Base[e]	B.t.u. per Cu. Ft.	Gal. Gasoline per M Cu. Ft.	Name	Age[f]	Character[g]	Porosity[h]	Net Thickness, Average in Feet	Structure[i]		Name	Depth of Hole, Ft.
1	y	y	37	y	P			Traverse	Dev	L	Por	15	A	1	Traverse	2,059
2	y	y	42	0.16	P			Dundee	Dev	L	Por	15	A	14	Dundee	3,292
3	y	y	41	0.41	P			Dundee	Dev	L	Por	21	A	1	Dundee	3,685
4	0	0	0	0	O	1,051	0.25	Stray-Marshall	Mis	S	Por	10	A	9	Monroe	4,042
5	y	y	42.4	0.25	P			Berea	Mis	S	Por	13	A	11	Dundee	2,760
6	0	0	0	0	O	1,060	y	Stray-Marshall	Mis	S	Por	5	A	19	Monroe	3,788
7	y	y	36	0.27	P			Dundee	Dev	L	Por	9½	A	26	Dundee	3,822
8	0	0	0	0	O	1,042	y	Stray	Mis	S	Por	5	A	7	Monroe	4,055
9	y	y	34	0.69	P	y	y	Dundee	Dev	L	Por	12.5	A	12	Dundee	2,707
10	y	y	42.4	0.52	P	1,044	y	G Stray-Marshall O. Monroe	Mis Dev	S D	Por	G.5 O.5	A	42	Monroe	3,520
11	y	y	43.2	0.11	P	y	y	G.Stray-Marshall O.Traverse	Mis Dev	S L	Por	G.5 O.4	A	8	Monroe	3,700
12	0	0	0	0	P	y	0	Parma	Pen	S	Por	10	MCY	12	Dundee	3,100
13	y	y	34	y	P			Traverse	Dev	L	Por	4	A	12	Dundee	2,407
14	y	y	43	1.50	P	y	y	Stray-Marshall Dundee Traverse	Mis Dev	S L L	Por	G.4 O.7.5	A	38	Monroe	4,390
15	y	y	37.4	0.35	P	1,032	1	Monroe	Dev	D	Por	10	A	49	St. Peters	4,754
16	y	y	42	0.02	P	y	2	Dundee	Dev	L	Por	15	A	30	Sylvania	4,821
17	0	0	0	0	O	1,000	y	Stray-Marshall	Mis	S	Por	5	A	8	Dundee	3,657
18	y	y	42	0.30	P	y	2	Dundee	Dev	L	Por	15	A	34	Monroe	3,677
19	0	0	0	0	O	885	y	Berea	Mis	S & D	Por	10	y	6	Dundee	2,306
20	y	y	43	0.25	P			Berea	Mis	S	Por	16	A	y	Sylvania	3,970
21	y	y	41.5	y	P	y	y	Traverse	Dev	L	Por	8	A	13	Dundee	1,950
22	y	y	47.8	0.39	P	0	0	Monroe	Dev	D	Por	6	A	10	Monroe	3,763
23	0	0	0	0	O	1,040	y	Stray-Marshall	Mis	S	Por	16	A	14	Monroe	3,529
24	y	y	44	0.30	P	1,046	y	G.Stray O.Monroe	Mis Dev	S L	Por	2	A	38	Monroe	3,907
25	y	y	36	0.03	P	0	0	Traverse Dundee	Dev	L	Por	T 5 D20	A	16	Sylvania	5,404
26	y	y	y	y	P	y	y	y	y	y	Por	y	y	y	y	
27																

TABLE 2.—*Summary of Drilling Operations in Michigan*

Important Wildcats Drilled in 1937

	County	Location			Total Depth, Ft.	Surface Formation	Deepest Horizon Tested
		Sec.	Twp.	Rge.			
1	Allegan	16	4 N	13 W	1590	Pleistocene	Traverse
2	Allegan	29	1 N	13 W	1360	Pleistocene	Traverse
3	Arenac	26	19 N	3 E	2044	Pleistocene	Traverse
4	Arenac	25	19 N	3 E	2002	Pleistocene	Traverse
5	Montcalm	13	10 N	5 W	3224	Pleistocene	Dundee
6	Gladwin	29	17 N	2 E	3525	Pleistocene	Dundee
7	Gladwin	10	17 N	1 E	3642	Pleistocene	Dundee
8	Gladwin	11	19 N	1 E	3542	Pleistocene	Dundee
9	Isabella	23	15 N	5 W	3807	Pleistocene	Dundee
10	Isabella	29	15 N	6 W	3751	Pleistocene	Monroe
11	Saginaw	5	11 N	2 E	2130	Pleistocene	Berea
12	Saginaw	1	N N	1 E	3197	Pleistocene	Dundee

Important Wildcats Drilled in 1937

	Drilled by	Initial Production per Day		Choke or Bean, in Fractions of an Inch	Pressure, Lb. per Sq. In.		Remarks
		Oil, U. S. Bbl.	Gas, Millions Cu. Ft.		Casing	Tubing	
1	Robert C. Lentz	20	0	*y*	*y*	*y*	Discovery well, Salem field
2	Jas. E. Flanigan and F. W. Kehlet	14	0	*y*	*y*	*y*	Important oil show leading to increased activity in southern Allegan County
3	E. H. Linabury	14	0	*y*	*y*	*y*	Discovery well, Adams-Arenac field
4	E. H. Linabury	65	0	*y*	*y*	*y*	Further confirmation of commercial Traverse production in Adams township
5	Bushnell Oil & Gas Co.	350	0	*y*	*y*	*y*	Extension of Crystal field to southeast
6	H. J. Hand	1500 ft. oil in hole	0	*y*	*y*	*y*	Discovery well, Bentley field
7	McClanahan Oil Co.	1200 ft. oil in hole	0	*y*	*y*	*y*	Important discovery between South Buckeye and Bentley fields
8	Whitehill, Clovis, & Drury	2800 ft. oil in hole	0	*y*	*y*	*y*	Important test in Secord township
9	Boston Oil & Gas Co.	2000 ft. oil in hole	0	*y*	*y*	*y*	Important test in Nottawa township
10	Ward J. Blunt	0	5 (est.)	*y*	*y*	*y*	Dundee dry hole. Encountered 5 million cu. ft. (est.) gas in Marshall
11	Mid-West Pet. Co.	8	0	*y*	*y*	*y*	Small Berea producer
12	Bond Oil Dev. Co.	1200 ft. oil in hole	0	*y*	*y*	*y*	Small Dundee producer in Saginaw County

	In Proven Fields	Wildcats
Number of wells drilling Dec. 31, 1937	48	37
Number of oil wells completed during 1937	602	12
Number of gas wells completed during 1937	66	2
Number of dry holes completed during 1937	109	160

Oil and Gas Development in Mississippi during 1937

By Henry N. Toler*

(New York Meeting, February, 1938)

Activity in the search for oil and gas in Mississippi was greater than it had been for several years. Interest manifested and exploration work in wildcat areas were at an all-time peak. Drilling activity in the state's two proven fields continued to decline; there being only four wells drilled in the Jackson field during the year. At the end of 1937 it seems very likely that 1938 will be a big year in the search for oil in Mississippi.

Drilling Activity

Jackson Gas Field.—The four wells drilled in the Jackson field during 1937 resulted in three producers and one dry hole. Nine producing gas wells were abandoned during the year because of salt-water encroachment. The total production for 1937 was 14,248,000,000 cu. ft., which was a billion and a quarter increase over 1936, the highest year prior to 1937. The grand total produced from the field is 72,341,000,000 cu. ft. of gas and over 15,000 bbl. of oil. The three wells that had produced oil the past few years were also abandoned during the year because of the small quantity of oil and the large volume of salt water.

Table 1.—*Oil and Gas Production in Mississippi for Year* 1937

Line Number	Field, *County*	Age, Years to End of 1937	Area Proved, Acres			Total Oil Production, Bbl.		Total Gas Production, Millions Cu. Ft.				Number of Oil and/or Gas Wells					Depth Average in Feet	
													During 1937		At End of 1937			
			Oil	Gas	Total	To End of 1937	During 1937	To End of 1937	During 1936	During 1937	Maximum Daily during 1937	Completed to End of 1937	Completed	Abandoned	Producing Gas Only	Total Producing	Bottoms of Productive Wells	To Top of Productive Zone
1	Amory, *Monroe*	12	0	640	640	0	0	1,461	36	30	¼	4	0	0	1	1	2,402	2,393
2	Jackson, *Hinds, Rankin*......	8	100	7,500	7,600	15,444	2,000	72,341	12,968	14,248	60	142	3	12	90	90	2,436	2,426

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The State of Mississippi's Fee Well No. 2, which was started in the latter part of 1936, was drilled to a depth of 5530 ft. to be the deepest well drilled in the Jackson field. No oil or gas was found below the Selma chalk, the regular producing horizon of the field. Below 3300 ft., which was the depth of the well at the end of 1936, the formations consisted of red, gray and dark shales and red and gray sandstones. Thin sills of igneous rock were penetrated at several points from 4400 ft. to the total depth. Igneous rock had also been penetrated from 2945 to 3007 ft. and from 3026 to 3205 ft. The age of the red section below 3300 ft. is considered to be Lower Cretaceous—Trinity in age. The well was plugged back to 2470 to 2480 ft. and completed as a gas well from the regular producing horizon. The State now has five producing gas wells on its property in the field, as the result of the State's drilling program of late 1936 and 1937.

Amory Gas Field.—The production from the Amory gas field continued to decline, and was only 30,000,000 cu. ft. in 1937. Total production from the field is 1,461,000,000 cu. ft. No wells were drilled in the field during the year and only one well continues to deliver gas to the pipe line.

ACTIVITY OUTSIDE PROVEN FIELDS

There were 19 wildcat wells abandoned during 1937, the deepest one being 6588 ft. None of these wells discovered new fields, but some of them were important in that they discovered salt domes or other types of structures or had showings of oil or gas. The information obtained from some of these wells will serve as a basis for future testing.

The Sun Oil Company's Scanlan and Semmes Well No. 1, which had discovered Mississippi's first salt dome at the end of 1936, was abandoned early in January 1937, at a depth of 4024 ft. in salt. The Sun Oil Co. drilled and abandoned three other wells on this dome: the Talley No. 1

TABLE 1.—(*Continued*)

Line Number	Pressure, Lb. per Sq. In.[d]			Character of Oil, Approx. Average during 1937					Character of Gas, Approx. Average during 1937		Producing Rock						Number of Dry and/or Near-dry Holes to End of 1937	Deepest Zone Tested to End of 1937	
	Initial	Average at End of		Gravity A.P.I. at 60° F.			Sulphur, Per Cent	Base[e]	B.t.u. per Cu. Ft.	Gal. Gasoline per M Cu. Ft.	Name	Age[f]	Character[g]	Porosity[h]	Net Thickness, Average in Feet	Structure[i]		Name	Depth of Hole, Ft.
		1936	1937	Maximum	Minimum	Weighted Average													
1	680	100		0	0	0	0	0	1,000	0	Hartselle	Mis	S	10	8	MU	3	Fort Payne	3,045
2	1,010	930	915	14	14	14	0	A	945	Dry	Selma	CreU	C	30	15	D	54	Trinity	5,530

[d] Footnotes to column heads and explanation of symbols are given on page 313.

at 2015 ft., in cap rock; the Talley No. 2 at 3034 ft. in cap rock (anhydrite); and the Talley No. 3 at 6588 ft. in cap rock (anhydrite). In the Talley Well No. 3 a significant discovery was the finding of 152 ft. of sand completely saturated with asphalt from 5643 to 5795 ft. Some thinner sands below this depth also carried asphalt. This definitely proves the existence of petroleum source beds in this section of Mississippi. This asphaltic sand was found just below the Selma chalk; probably it is Eutaw or Tuscaloosa in age. It is possible for either of these formations to be reached with the drill and be in a position to produce oil or gas in an area covering over two-thirds of the state. The Sun Oil Co. is now drilling a fifth well on this dome, the Talley Well No. 4, at the depth of 7643 feet.

TABLE 2.—*Summary of Drilling Operations in Mississippi*

Important Wildcats Drilled in 1937

	County	Location			Total Depth, Ft.	Surface Formation	Deepest Horizon Tested	Drilled by	Remarks
		Sec.	Twp.	Rge.					
1	Amite	29	4 N	2 E	5,224	Miocene	Wilcox	J. P. Wemple, Trustee	Dry
2	Bolivar	2	24 N	7 W	6,009	Recent Alluvium	Paleozoic	Phillips Petroleum Co.	Dry
3	Franklin	18	5 N	3 E	5,011	Miocene	Wilcox	F. E. Courson et al.	Dry. Show gas at 760 ft.
4	George	9	1 S	8 W	4,692	Miocene	Midway or Wilcox	Cleve Love et al.	Dry. Junked the hole
5	Hancock	17	9 S	14 W	2,502	Coastal Terrace Deposit	Miocene	American Sulphur Co.	Dry
6	Hinds	12	5 N	4 W	3,012	Vicksburg	Wilcox	R. R. Chichester et al.	Dry
7	Hinds	35	6 N	4 W	4,346	Catahoula	Salt	Southern Natural Gas Co.	Dry. Show gas in cap rock at 2910 ft.
8	Lamar	28	4 N	15 W	4,024	Miocene	Salt	Sun Oil Co.	Dry
9	Lamar	28	4 N	15 W	2,015	Miocene	Cap rock (lime)	Sun Oil Co.	Dry
10	Lamar	33	4 N	15 W	3,034	Miocene	Cap rock (anhydrite)	Sun Oil Co.	Dry
11	Lamar	33	4 N	15 W	6,588	Miocene	Cap rock (anhydrite)	Sun Oil Co.	Dry. All Cretaceous sands carrying asphalt
12	Lauderdale	34	7 N	15 W	1,580	Wilcox	Selma chalk	R. E. Dalton et al.	Dry
13	Madison	1	8 N	2 W	5,034	Jackson	Selma chalk	Sun Oil Co.	Dry
14	Perry	2	2 N	10 W	3,027	Miocene	Claiborne	F. E. Courson et al.	Dry
15	Wilkinson	1	2 N	2 W	5,016	Miocene	Claiborne	H. L. Carnahan et al.	Dry
16	Wilkinson	4	3 N	1 E	4,048	Miocene	Claiborne	Charles Green et al.	Dry. Show of oil at 2378 to 2385 ft.
17	Wilkinson	32	4 N	2 W	3,815	Miocene	Claiborne	A. B. Taylor et al.	Dry
18	Wilkinson	34	4 N	1 W	5,559	Miocene	Wilcox	A. B. Taylor et al.	Dry
19	Yalobusha	26	24 N	6 E	906	Wilcox	Midway (?)	Skuna Development Co.	Dry

	In Proven Fields	Wildcats
Number of wells drilling Dec. 31, 1937	0	15
Number of oil wells completed during 1937	0	0
Number of gas wells completed during 1937	3	0
Number of dry holes completed during 1937	1	19

Another very important discovery was that made by the Southern Natural Gas Company's Angelo-Williams Well No. 1, sec. 35-5 N.-4 W., Hinds County, when salt was encountered at 3026 ft., thus discovering the second salt dome in Mississippi. This well was abandoned at 4346 ft. in salt. Several other tests on this dome are to be made in the immediate future.

These two salt domes are widely separated and it seems that there may be a big basin in south central Mississippi in which many salt domes and other types of structures will be located. In addition, other structures have been indicated by some of the wells drilled or now drilling.

Geophysical work was greater in Mississippi during 1937 than at any other time. About 20 parties were working continuously or at some time during the year. This work was scattered over many sections of the state, the greater amount being done in south central and south Mississippi. It is indicated and reported that many salt domes and other types of structures have been located by geophysical work. This remains to be determined definitely by drilling.

Leasing has kept pace with the drilling and other exploration work, with about 50 blocks of acreage having been taken during 1937. There are approximately 4,000,000 acres now under lease to major companies and a few independent operators.

At the end of 1937, fifteen wildcat wells were drilling in the state, some of which will be deep tests. It now appears that 1938 will be the biggest year yet experienced in Mississippi in the search for oil and gas.

Development of Oil and Gas in Missouri in 1937

By Frank C. Greene*

(New York Meeting, February, 1938)

Missouri has had one of the best years in history in the development of gas, the 49 completed gas wells having an average of nearly 1,000,000 cu. ft. initial open flow. Altogether 101 wells were drilled in the western part of the state, from Andrew County on the north to Vernon County on the south. Of these 49 were gas wells (including four old wells drilled deeper) with an initial open flow of 48,850,295 cu. ft., eight were oil wells (including one old well drilled deeper) with an initial capacity of 125 bbl. per day and 44 were dry holes (including five old wells drilled deeper). All the oil wells were in previously discovered pools in Jackson and Cass Counties.

The outstanding discovery was a "shoestring" of a sand that is termed the Bartlesville, trending northwest and southeast across townships 48 and 49 N., R. 32 W., in central Jackson County. The sand is believed to be a narrow channel or bar, probably not over 800 ft. wide, lying at a higher horizon than the Bluejacket or true Bartlesville sand. A total of 32 wells with 47,453,080 cu. ft. initial open flow has been completed along the 6 miles of the shoestring. The largest individual well had an open flow of 4,500,000 cu. ft. The depth of these wells ranges from 350 to 635 ft., depending on surface elevation. The rock pressure ranges from 145 to 169 pounds.

The Missouri Valley Gas and Oil Co. and Panhandle Eastern Pipe Line Co. have laid pipe lines into the area and most of the wells are now connected.

In other parts of Jackson County and in other counties of the state there was very little activity during 1937. Of the 101 completions, 88 were in Jackson County. Cass County had five oil wells and three dry holes, Bates County one dry hole and Vernon County two dry holes. In the northern counties, Andrew and Clinton were represented by one dry hole each.

At the end of 1937 drilling and leasing operations were very active and wildcatting promises to feature the coming year.

Manuscript received at the office of the Institute Jan. 26, 1938. Published by permission of H. A. Buehler, State Geologist.

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Oil and Gas Development in Montana for 1937

By Eugene S. Perry*

The oil and gas industries in Montana continued through the year of 1937 with but little change. No new fields were discovered, and production of old fields did not vary greatly. No outstanding wildcat wells were drilled. Perhaps most notable were extensions in the western part of the Kevin-Sunburst field. Acid treatment of wells in the Kevin and Pondera fields continued with gratifying results.

Table 1.—*Oil and Gas Production in Montana*

Line Number	Field, *County*	Age, Years to End of 1937	Area Proved, Acres			
			Oil	Oil and Gas[a]	Gas	Total
1	Baker-Glendive, *Fallon, Dawson, Wibaux, Prairie*	Gas 22 Oil 2	40*x*		50,000	50,000
2	Border (Red Coulee), *Toole*	7	300	0	5	300
3	Bowdoin-Saco, *Phillips, Valley*	15	0	0	50,000*x*	50,000*x*
4	Bowes, *Blaine*	11	0	0	3,000	3,000
5	Boxelder, *Hill*	6	0	0	1,000*y*	1,000*y*
6	Cat Creek, *Petroleum (Garfield)*	17	1,600	0	0	1,600
7	Cut Bank, *Glacier*	8	38,000	0	30,000*y*	68,000
8	Devils Basin, *Musselshell*	18	600	0	0	600
9	Dry Creek, *Carbon*	8	*y*	2,000	*y*	2,000
10	Elk Basin {Montana, Wyoming} *Carbon (Mont.)*	22	200	0	0	200
11	Hardin, *Big Horn*	9	0	0	5,000	5,000
12	Kevin-Sunburst, *Toole*	15	45,000[1]	0	50,000[2]	95,000
13	Lake Basin, *Stillwater*	10	100	0	1,000	1,100
14	Pondera, *Pondera, Teton*	9	4,500	0	0	4,500
15	Whitlash, *Liberty (Toole)*	Gas 19 Oil 5	500*x*	0	5,500	6,000

[a] Footnotes to column heads and explanation of symbols are given on page 313.
[1] Madison lime.
[2] Sunburst sand.

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* Montana School of Mines, Butte, Mont.

Total oil production for 1937 was 5,839,272 bbl. (Fig. 1). Gas production was approximately 23,000,000,000 cubic feet.

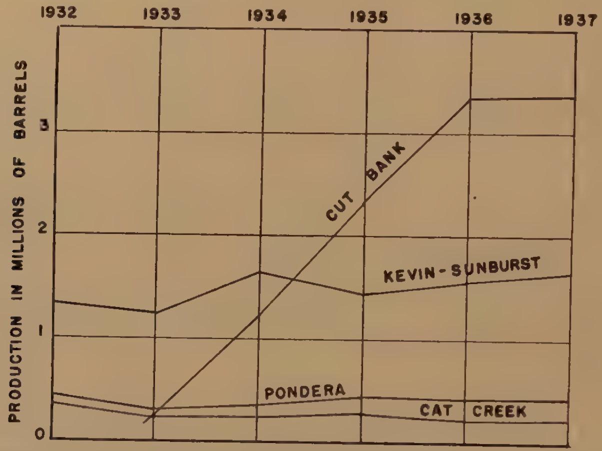

FIG. 1.—ANNUAL OIL PRODUCTION OF LEADING FIELDS, MONTANA. PRODUCTION FROM OTHER FIELDS WAS SMALL.

TABLE 1.—(*Continued*)

Line Number	Total Oil Production, Bbl.				Total Gas Production, Millions Cu. Ft.				Number of Oil and/or Gas Wells				
										During 1937		At End of 1937	
	To End of 1937	During 1936	During 1937	Daily Average during Nov. 1937	To End of 1937	During 1936	During 1937	Maximum Daily during 1937	Total Completed to End of 1937	Completed	Abandoned	Temporarily Shut Down	Producing Oil Only
1	15,000				57,579	7,325	7,250	35	200	4	2	*y*	2
2	Included with Kevin-Sunburst				*x*	0	0	0	19	0	0	*y*	18
3	0	0	0	0	4,025*y*	845	850*y*	*y*	35	0	0	*y*	0
4	0	0	0	0	5,680*y*	682	680*y*	*y*	9	0	0	0	0
5	0	0	0	0	Included with Bowes				3	0	0	0	0
6	13,532,000	254,239	223,606	*y*	0	0	0	0	228	0	1	43	104
7	10,377,000	3,284,000	3,335,000	7,108	40,277	8,808	9,839	39.5	444	78	0	88	301
8	*y*	1,493	1,362	*y*	0	0	0	0	19	1	1	1	1
9	871,022	212,561	99,140	*y*	2,163	749	750	6	14	1	0	0	8
10	752,674	11,873	8,994	*y*	0	0	0	0	35	0	0	0	30
11	0	0	0	0	185*y*	65*y*	*y*	*y*	28	1	1	0	0
12	33,421,160	1,685,909	1,675,405	3,928	24,822	2,675	2,500*y*	*y*	2,300	98	20	Oil 287	765
13	365,611	15,144	18,412	*y*	Gas wells shut down				28	0	0	Oil 3 Gas 12	2
14	4,844,298	421,395	413,670	*y*	Small field use only				161	0	0	1	159
15	39,817	8,900	6,526	*y*	4,056	736	707	*y*	17	2	2	5	4 Shut down

The extensions to the Kevin-Sunburst field consisted of about 70 new wells within and immediately adjacent to the main field discovered in 1923 near Kevin. Acidization was responsible for considerable increase in commercial production in wells in this area that found oil in the Madison (Mississippian) limestone. However, somewhat localized areas of oil-saturated Lower Cretaceous sandstone (Kootenai, Sunburst) were discovered. Ordinarily this horizon yields gas only near Kevin. In volume most of the new wells initially ranged from 50 to 200 bbl. per day by pumping.

The market in northern Montana was greatly reduced late in 1937 by the discovery and development of a prolific high-gasoline-content oil field immediately west of the unique Turner Valley gas field in Alberta, about 125 miles north of the international boundary. This oil field, only half drilled, had a potential production of approximately 25,000 bbl. per day in December 1937, and prorated at 35 per cent was yielding 9000 bbl. per day to a market originally supplied by northern Montana. Producers in Montana with refining outlets disposed of much of the yield of their wells, but small independents relying upon the open market were confronted by no demand. Prices fluctuated. The Governor of

TABLE 1.—(*Continued*)

Line Number	Number of Oil and/or Gas Wells, At End of 1937: Producing Oil and Gas[b]	Producing Gas Only	Total Producing	Depth, Average in Feet: Bottoms of Productive Wells	To Top of Productive Zone	Oil Production Methods at End of 1937, Number of Wells: Flowing	Pumping	Pressure, Lb. per Sq. In.[d]: Initial	Average at End of 1936	1937	Character of Oil, Approx. Average during 1937: Gravity A.P.I. at 60° F.: Maximum	Minimum	Weighted Average	Sulphur, Per Cent	Base[e]
1		100	102	Oil 6,700 Gas 775	6,500 750	1	1	Oil 700 Gas 210 420	*y*	*y*	31	29	30	0.1	M
2	0	0	18	2,520	2,500	0	19	*y*	*y*	*y*			37	1.0	M
3	0	24	24	720 820	700 800	0	0	217	125	*y*	0	0	0	0	
4	0	8	8	1,100	1,000	0	0	260	*y*	*y*	0	0	0	0	
5	0	3	3	1,300	1,200	0	0	430	*y*	*y*	0	0	0	0	
6	0	0	143	1,465	1,425	0	104	*x*	*x*	*y*			49	0.5	M
7	0	55	356	2,850	2,830	8	372	725	*y*	600*y*	39.6	35.4	38	1.0	M
8	0	0	2	1,190	1,180	0	2	*x*	*x*	*x*			18±	*y*	A
9	0	6	14	4,500–5,750	4,400–5,650	4	4	1,600	*y*	*y*			50	0.02	P
10	0	0	30	1,100	1,000	0	30	*x*	*x*	*y*			43	0.14	M
11	0	27	27	745	725	0	0	137	*y*	*y*	0	0	0	0	
12	0	143	908	Gas 1,200 Oil 1,560	1,220 1,560	0	1,052	Gas 360 Oil *x*	*y*	Gas 190 Oil<100	40	28	29.7	1.6	M
13	0	0	Oil 5 Gas 12	1,440 3,290 3,935	1,240 2,990 3,835	0	5	220	*y*	*y*			43.6	0.1	P
14	1	1	161	1,930	1,950	0	161	*y*	*y*	*y*	31.4	30	31	1.9	M
15	0	12	17	1,600–1,700 2,000–2,100		0	4	Col 275 330 Koot 600	*y*	*y*	38.3	34.3	36	0.8	M

Montana ordered a hearing by the Oil Conservation Board. Numerous witnesses were examined and cross-examined by lawyers chosen for the purpose. The decision of the Board was that state-controlled proration is not necessary and not advisable at present. However, a bill of exceptions was filed with the Board to be presented to the Governor. Perhaps the most important result is a movement for Montanans to "buy gasoline made from Montana crude"—a movement that has resulted in improved markets for northern Montana at the expense of Wyoming, Oklahoma and California producers.

Montana has new potential oil and gas territory. Much is to be classed as "wildcat," although extensions to known fields are to be expected. Depending on market conditions and governmental activities, prospecting will expand or dwindle during 1938.

TABLE 1.—(*Continued*)

Line Number	Character of Gas, Approx. Average during 1937		Producing Rock						Number of Dry and/or Near-dry Holes to End of 1937	Deepest Zone Tested to End of 1937	
	B.t.u. per Cu. Ft.	Gal. Gasoline per M Cu. Ft.	Name	Age[f]	Character[g]	Porosity[h]	Net Thickness, Average in Feet	Structure[i]		Name	Depth of Hole, Ft.
1	995	0	Gas Judith River Oil Madison	CreU MissL	SH L	15± x	20 to 80 20±	A		Devonian	8,186
2			Kootenai	CreL	S	14	12	T	8	Kootenai	2,600
3	990	0	Colorado	CreU	SH	x	10–30	D	3	Base of Chester	3,180
4	970	0	Eagle	CreU	S	16±	100	AF	1	Madison (Mis)	4,700
5	980	0	Eagle	CreU	S	16±	100	A	1	Eagle	1,300
6	0	0	Kootenai	CreL	S	15±	40	AF	52	Madison	4,124
7	1,010	⅛	Kootenai	CreU	S	13	12	ML	68	Madison	3,160
8			Big Snowy (Chester)	MissU	S	x	10	D	10	Madison	1,800
9	1,100	¼	Gas Eagle Gas Frontier Oil Cloverly	CreU CreL	S S	y	70 45	AF	2	Tensleep (Pen)	6,887
10	0		Frontier	CreU	S	y	30± 40	AF	3	Cloverly (CreL)	3,000
11	990	0	Colorado	CreU	S	x	20	T	1	Tensleep	4,120
12	950–990	0	Gas Kootenai Oil Madison	CreL MissL	S L	10–18 10–40	20 10	D	582	Pre-Cambrian	4,520
13	1,010–1,050	y	Gas Eagle Oil Frontier Oil Dakota	CreU CreL	S	x	100 40 30	D	11	Dakota (CreL)	4,100
14			Madison	MissL	L	10–30	10–30	N	22	Madison	2,000
15	996	0	Colorado (Kootenai)	CreU CreL	S S	12–18 14	20–30 25	D	15	Madison	2,205

Oil and Gas Development in New Mexico in 1937

By E. H. Wells,* Member A.I.M.E., and A. Andreas†

New Mexico retained its position as the sixth largest oil-producing state for the year 1937 with a total production of 38,484,630 bbl. This was an increase of 11,680,184 bbl. over the 1936 production of 26,804,446 bbl., or a gain of 43 per cent.

The production for Lea County during 1937 was 35,961,056 bbl.; for Eddy County, 2,136,251 bbl.; and for northwestern New Mexico (San Juan and McKinley Counties), 387,323 bbl. The average daily non-marginal well allowable for Lea County on Jan. 1, 1937, was 92 bbl.; at the close of the year it was 67 bbl. The average daily pipe-line runs were less than the allocations of the New Mexico Oil Conservation Commission, but slightly in excess of the state allowables recommended by the United States Bureau of Mines. The average daily production for the year was 105,437 barrels.

The total number of completions in the state was 742, of which 638 were oil wells; 19 hydrocarbon gas wells; 5 carbon dioxide gas wells and 80 dry holes. Of the dry holes, 46 were in proven fields. Of these 46 dry holes, 13 were in the Artesia-Grayburg-Jackson-Maljamar area, Eddy County, two in the Getty Extension field, Eddy County, 11 in the Red Mountain field, McKinley County, three in the Rattlesnake field, San Juan County, and nine in the Aztec-Bloomfield area, San Juan County. There were only eight dry holes in the proven fields in Lea County.

SOUTHEASTERN NEW MEXICO

Lea County.—The Monument field was the largest producing field in Lea County, with 10,945,788 bbl., closely followed by the Eunice field with 10,927,929 bbl. The Hobbs field, formerly the largest producing field in Lea County, was relegated to third place, with 7,292,522 barrels. Drilling during the year closed the gap between the northern part of the Eunice field and the southern part of the Monument field. The wells in this area were relatively small, because of decreased porosity in the lime.

The greatest activity in Lea County was in the Monument pool, with 199 completions, 197 being oil wells, one a gas well and one a dry hole.

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The limits of this pool were not defined on the west, northwest or north. The total number of 40-acre oil-producing units in the field at the close of the year was 460.

Drilling during the year developed an important pool in the Vacuum area. The first well drilled in this area was the Texas Inglefield-Bridges State No. 1 in sec. 4, T. 17 S., R. 34 E. An estimated potential production of 100 bbl. a day was obtained. The well was drilled to a total depth of 5329 ft., and plugged and abandoned May 15, 1928.

The second well drilled in the area was the Magnolia State Bridges A-1 on the section line between secs. 13 and 14, T. 17 S., R. 34 E. The hole was temporarily abandoned at 4900 ft. in July, 1929. It was estimated at that time that the well would produce 100 bbl. daily.

In November 1936, the Magnolia Petroleum Co. spudded its State G-1 in the NW¼ NW¼ NE¼ sec. 24, T. 17 S., R. 34 E., approximately ¾ mile southeast of its State Bridges A-1 well, and completed it in February 1937 as a 150-bbl. pumping well.

TABLE 1.—*Oil and Gas Production in New Mexico*

Line Number	Field, *County*	Age, Years to End of 1937	Area Proved, Acres			
			Oil	Oil and Gas[a]	Gas	Total
1	Artesia, *Eddy*	14	11,940	*y*	2,840	14,780
2	Aztec, *San Juan*	13	90	0	5	95
3	Blanco, *San Juan*	10	0	40	0	40
4	Cooper, *Lea*	8	*y*	3,520	120	3,640
5	Eaves, *Lea*	8	680		160	840
6	Eunice, *Lea*	9	*y*	17,640*y*	120	17,760
7	Getty, *Eddy*	9	240			240
8	Hardy, *Lea*	2	1,520	*y*	0	1,520
9	Hobbs, *Lea*	9	1,800	8,240	0	10,040
10	Hogback, *San Juan*	15	160	0	0	160
11	Hospah, *McKinley*	10	50	0	0	50
12	Jal, *Lea*	10	*y*	1,200*y*	480	1,680
13	Kutz Canyon, *San Juan*	10	0	0	1,200	1,200
14	Langlie, *Lea*	10	*y*	2,120	320	2,440
15	Lynch and N. Lynch, *Lea*	8	520	0	0	520
16	Lynn, *Lea*	8	440	0	0	440
17	Mattix, *Lea*	1	1,920	0	120	2,040
18	Monument, *Lea*	3	*y*	18,520*y*	40	18,560
19	Penrose, *Lea*	2	*y*	3,240*y*	0	3,240
20	Rattlesnake, *San Juan*	13	640	0	0	640
21	Red Mt., *McKinley*	2	20	0	0	20
22	Rhoades, *Lea*	10	0	120	120	240
23	Skelly, *Lea*	2	*y*	1,360*y*	80	1,440
24	South Eunice, *Lea*	8	*y*	1,720*y*	160	1,880
25	Table Mesa, *San Juan*	12	100	0	0	100
26	Ute Dome, *San Juan*	15	0	0	640	640
27	Vacuum, *Lea*	9	200	0	0	200
28	Total		20,320	57,720	6,405	84,445

[a] Footnotes to column heads and explanation of symbols are given on page 313.

After the completion of the Magnolia State G-1 the Texas Co. spudded in its State L-1 in the SW¼ NE¼ sec. 1, T. 18 S., R. 34 E., in September 1937, and completed it in November 1937 at a depth of 4497 ft. The initial production was 820 bbl. of oil at 34.4° Bé. gravity with a gas-oil ratio of 1360. This well definitely proved that a large oil field had been discovered.

It is anticipated that the Vacuum area will have the greatest activity of any of the New Mexico fields during 1938. The State of New Mexico owns most of the acreage in the probable producing area.

Eddy County.—Two new fields were discovered during the year in New Mexico, one in the Black River dome area, Eddy County, and the other about 2½ miles east of the Getty field, Eddy County.

The discovery well at the Black River dome, the Collins Weiler No. 1 in sec. 13, T. 24 S., R. 26 E., was drilled to a depth of 2918 ft. and was considered a small producer. An offset to this well also encountered oil, but it was not a completion at the end of the year. This may prove to be the first commercial field discovered west of the Pecos River.

TABLE 1.—(*Continued*)

Line Number	Total Oil Production, Bbl.				Total Gas Production, Millions Cu. Ft.				Number of Oil and/or Gas Wells		
										During 1937	
	To End of 1937	During 1936	During 1937	Daily Average during Nov. 1937	To End of 1937	During 1936	During 1937	Maximum Daily during 1937	Completed to End of 1937	Completed	Abandoned
1	9,269,714	1,071,806	2,004,303	7,269	750*x*	*x*	*x*	*x*	423	47	*x*
2	30,129*y*	2,113	3,860*y*		0	0	0	0	28	0	0
3	1,226	50	70		166	24	35	0.2	1	0	0
4	7,847,289	2,929,397	2,237,931	4,963	51,713	14,631	14,747	*x*	92	5	0
5	455,022	*y*	386,844	1,063	455	*x*	386	*x*	21	6	0
6	23,599,176	7,890,940	10,927,929	27,025	82,856	20,858	38,367	*x*	444	136	
7	282,414	23,057	131,948	362					9		
8	384,795	66,575	318,220	1,198	748	148	600	1.5	38	27	0
9	80,533,071	9,052,129	7,292,522	16,270	174,676	14,516	15,817	*y*	265	7	0
10	1,809,025	84,657	69,875	232	0	0	0	0	7	0	0
11	9,000	*y*	2,500*y*		0	0	0	0	3	0	0
12	5,367,365	1,104,417	435,881	1,185	16,938*y*	13,528	3,410	*y*	42	3	0
13	0	0	0	0	5,648	1,192	1,164	4.7	10	0	0
14	796,364	*y*	604,846	2,410	3,439	*x*	2,612	*x*	61	45	0
15	6,322,864	432,871	316,625	713	0	0	0	0	18	0	0
16	120,592	*y*	97,838	506	175	*y*	142	*x*	18	10	0
17	583,876	59,510	524,366	2,064	672	68	604	*x*	52	36	0
18	14,763,090	3,579,908	10,945,788	30,447	39,443	7,165	29,444	*x*	464	198	0
19	1,037,528	205,938	831,590	3,506	1,764	349	1,415	*x*	81	66	0
20	3,813,064	291,404	279,845	815	0	0	0	0	49	6	7
21	2,800*y*	1,600*y*	1,200*y*	4	0	0	0	0	6	2	1
22	121,746	*y*	30,172	120	7,750	*x*	1,920	*x*	6	2	0
23	515,911	*y*	423,114*y*	1,524	0.3	*x*	0.2	*x*	39	25	0
24	990,373	*y*	579,664	2,314	495	*x*	289	0.6	47	32	0
25	451,890	31,131	29,973	86	0	0	0	0	6	0	0
26	0	0	0	0	3,911*y*	452	668	6.5	3	0	0
27	7,726	0	7,726	80	*x*	*x*	*x*	*x*	5	4	0
28	159,106,050	26,827,503	38,484,630		391,599.3	72,931	111,620.2		2,238	657	8

The Barber field was discovered in February. In that month the Neil Wills Colgalzier No. 1 in sec. 20, T. 30 S., R. 30 E., was completed at 1443 ft. Its initial production was 132 bbl. oil on swab, the gravity being 20.5° Bé. Four oil wells with an average initial production of about 200 bbl. were drilled in the area during the year, and also two dry holes.

At the close of the year the Shugart Coulthard No. 1 well in sec. 35, T. 18 S., R. 31 E., was swabbing and flowing around 60 bbl. of oil daily at a depth of 3727 ft., but was not a completion. This well is approximately 9 miles south of the Skelly section of the Artesia-Grayburg-Jackson-Maljamar area.

In the early part of 1937 a 5½-in. oil line was constructed from the Artesia-Grayburg-Jackson-Maljamar area to connect with the line of the Texas Pipe Line Co. at Lea. This line approximately doubled the market outlet for the Eddy County fields.

TABLE 1.—(*Continued*)

	Number of Oil and/or Gas Wells					Depth, Average in Feet		Oil Production Methods at End of 1937				Pressure, Lb. per Sq. In.[d]			Character of Oil, Approx. Average during 1937				
	At End of 1937							Number of Wells					Average at End of		Gravity A.P.I. at 60° F.				
Line Number	Temporarily Shut Down	Producing Oil Only	Producing Oil and Gas[b]	Producing Gas Only	Total Producing	Bottoms of Productive Wells	To Top of Productive Zone	Flowing	Pumping	Gas-lift	Injection into Reservoir[c]	Initial	1936	1937	Maximum	Minimum	Weighted Average	Sulphur, Per Cent	Base[e]
1	*y*	207*y*	65*y*	4	276	2,251		65	207		0	*x*	*x*	*x*	39.6	35	37.1	0.87	M
2	8	16	0	0	16	1,075	750	0	16	0	0	e0	e0	e0	58	50	55	0.08	P
3	0	0	0	1	1	4,550	4,250	0	0	0	0	e1,200	e1,120	e1,100	55	50	54	0.13	P
4	0	*y*	88*y*	4	92	3,570		56	13	19	0	*x*	e1,300*y*	e1,250*y*			29	*x*	P
5	0	17	0	4	21	3,300		13	4	0	0	*x*	*x*	e1,247			28.5	1.90	P
6			441	3	444	3,885		425	10	6	0	*x*	e1,332	e1,250*y*			28.5	1.97	P
7		6			6	1,380	1,365		6						*y*	*y*	22*y*	*x*	A
8	0	38	0	0	38	3,750		32	6	0	0	*x*	*x*	*x*			33	1.80	P
9	0	*y*	262	0	262	4,174	4,050	249	11	2		e1,550	e1,228	e1,201	35.5	35	35.3	1.47	M
10	0	7	0	0	7	714	705	7	0	0	0	e215	e155	e150	60	60	60	0.08	P
11	3	0	0	0	0	1,651	1,640	0	0	0	0	*x*	*x*	*x*	30.2	29	29.7	0.15	M
12	0	0	30	12	42	3,327		16	10	4	0	*y*	*y*	*y*			28.5	1.97	P
13	1	0	0	10	10	1,900	1,840	0	0	0	0	e565	e500	e480	0	0	0	0	
14	0	0	53	8	61	3,583		49	1	3	0	*x*	*x*	e1,089	*y*	*y*	28	1.90	P
15	0	13	0	0	13	3,771		0	13	0	0	*x*	*x*	*x*	*y*	*y*	27	1.53	P
16	0	11	0	3	14	3,875		8	0	3	0	*x*	*x*	*x*	*y*	*y*	29	*y*	P
17	0	48	0	4	52	3,545		43	5	0	0	*x*	*x*	e1,200	*y*	*y*	29	*y*	P
18	3	*y*	460*y*	1	461	3,940		450	7	3	0	e1,427	e1,409	e1,353	*y*	*y*	34	*y*	P
19	0	*y*	81*y*	0	81	3,650		74	7	0	0	*x*	*x*	e1,000	*y*	*y*	34	*y*	P
20	2	25	0	0	25	808	784	0	25	0	2	*y*	*y*	*y*	87	60	60	0.05	P
21	2	3	0	0	3	457	438	0	3	0	0	e0	e0	e0	43	41	42	0.01	M
22	0	*y*	3	3	6	3,450		3	0	0	0	*x*	*x*	e1,278	*y*	*y*	*y*	*y*	P
23	2	*y*	34	3	37	3,666		27	7	0	0	*x*	*x*	*x*	*y*	*y*	34	*y*	P
24	0	*y*	43	4	47	3,856		41	2	0	0	*x*	*x*	e1,355	36	32	34	*y*	P
25	0	6	0	0	6	1,337	1,325	0	6	0	0	e0	e0	e0	57	56	56.5	0.04	P
26	0	0	0	3	3	2,350	2,285	0	0	0	0	e720	e550	e525	0	0	0	0	
27	0	5	0	0	5	4,500	4,300*y*	5	0	0	0	e1,510	*x*	e1,510	39	32	35	*y*	P
28	21	402	1,560	67	2,029			1,563	359	40	2								

NORTHWESTERN NEW MEXICO

In San Juan County most of the drilling was confined to the Rattlesnake field, with the completion of six oil wells, three dry holes, and the abandonment of seven old wells in the field.

In McKinley County the small Red Mountain field proved to be a disappointment. Two small producing oil wells and eleven dry holes were drilled in this area during the year. At the end of the year there were six producing wells in the area, and the estimated production for 1937 was 1200 bbl. Production is obtained in the Mesa Verde formation, Upper Cretaceous, at a depth of approximately 440 feet.

NORTHEASTERN NEW MEXICO

In the northeastern part of the state the greatest activity was in the Bueyeros field, Harding County, with the drilling of five carbon dioxide gas wells. Four of them were completed in the upper gas horizon at

TABLE 1.—(*Continued*)

Line Number	Character of Gas, Approx. Average during 1937		Producing Rock						Number of Dry and/or Near-dry Holes to End of 1937	Deepest Zone Tested to End of 1937		Reference to Text[j]
	B.t.u. per Cu. Ft.	Gal. Gasoline per M Cu. Ft.	Name	Age[f]	Character[g]	Porosity[h]	Net Thickness, Average in Feet	Structure[i]		Name	Depth of Hole, Ft.	
1	y	y	Upper San Andres	Per	D		x	AM	121	Permian	4,412	
2	1,153	x	Farmington sand	CreU	S		25	S	47	Lewis Sh, CreU	2,665	A
3	1,050	y	Pictured Cliffs	CreU	S		x	H	18	Mesa Verde, CreU	4,550	A
4	x	x	White lime	Per	D	Cav		A	4	L. San Andres Per	5,095	A
5	y	y	Permian sand	Per	S			A	2	San Andres Per	3,542	
6	y	y	White lime	Per	D	Cav		A	6	San Andres Per	4,404	A
7			Capitan	Per	LS		20	A	3	Pennsylvanian?	6,630	
8	y	y	Permian sandstone and White lime	Per	S-D	Cav		A	0	San Andres Per	3,815	A
9	1,150	1.98	White lime	Per	D	Cav	123	A	11	San Andres Per	4,500	A
10	0	0	Dakota sand	CreU	S		9	D	9	McElmo-CreL	1,225	A
11			Hospah sand	CreU	S		11	DF	12	Dakota Ss-CreU	3,282	A
12	y	y	White lime	Per	D	Cav		A	2	San Andres Per	4,125	A
13	1,050	0.2y	Pictured Cliffs	CreU	S		60	H	12	Mesa Verde CreU	4,400	A
14	y	y	Permian sand	Per	S			A	4	San Andres Per	3,903	
15			White lime	Per	D	Cav		AM	16	San Andres Per	4,046	
16	y	y	Permian sandstone and White lime	Per	D	Cav		A	2	San Andres Per	5,095	
17	y	y	Permian sand	Per	S			A	2	San Andres Per	3,853	
18	y	y	White lime	Per	D	Cav		A	5	San Andres Per	4,534	
19	y	y	Permian sand	Per	S			A	2	San Andres Per	4,073	
20	0	0	Dakota sand	CreU	S		24	AF	19	PennU	7,370	A
21	0	0	Mesa Verde	CreU	S		13	AF	19	Mesa Verde CreU	640	A
22	y	y	Permian sand	Per	S			A	3	San Andres Per	4,115	
23	y	y	Permian sand	Per	S			A	3	San Andres Per	4,052	
24	y	y	White lime	Per	D	Cav		A	1	San Andres Per	6,202	
25	0	0	Dakota sand	CreU	S		7	A	7	Chinlee-TriasU	3,010	A
26	1,060	0.2y	Dakota sand	CreU	S		60	D	0	Dakota Ss-CreU	2,350	A
27	y	y	White lime	Per	D	Cav	200y	A	5	San Andres Per	5,329	
28									335			

depths of less than 1000 ft., and one well was completed in the lower horizon at a total depth of 2041 feet.

The initial daily production of the wells completed in the upper horizon is 2,000,000 to 3,000,000 cu. ft. with a pressure of approximately 400 lb. The initial production of the deep well located in sec. 31, T. 20 N., R. 31 E., was estimated to be 20,000,000 to 30,000,000 cu. ft. of gas containing approximately 99 per cent of carbon dioxide. The pressure was estimated to be about 600 pounds.

During the year two small experimental dry-ice plants were completed in the Bueyeros field, but production was negligible.

ACKNOWLEDGMENTS

The authors are indebted to Mr. John A. Frost, District Engineer, United States Geological Survey, Farmington, New Mexico, for informa-

TABLE 2.—*Summary of Drilling Operations in New Mexico* 1937

SURFACE FORMATION, TERTIARY; DEEPEST HORIZON TESTED, PERMIAN

Important Wildcats Drilled in 1937

	County or Local Division	Location			Total Depth, Feet or Meters	Drilled by	Initial Production per Day		Remarks
		Sec.	Twp.	Rge.			Oil, U. S. Bbl.	Gas, Millions Cu. Ft.	
1	Lea........	31	17 S	37 E	5300	Ajax Drill Co.			Abandoned
2	Lea........	5	20 S	38 E	4410	Baldridge			Abandoned
3	Lea........	8	21 S	38 E	4401	Brown et al.			Abandoned
4	Lea........	22	21 S	34 E	4144	Brown et al.			Abandoned
5	Lea........	7	16 S	36 E	5512	Carlock			Abandoned
6	Lea........	35	20 S	38 E	4842	Continental			Abandoned
7	Lea........	30	20 S	38 E	3860	Continental	1248		NE. extension of Eunice
8	Lea........	2	11 S	36 E	5277	Crandall & Osmond			Abandoned
9	Lea........	2	21 S	32 E	3500	Culberson & Irwin			Abandoned
10	Lea........	12	26 S	32 E	4868	Homestead O. & G.			Abandoned
11	Lea........	9	22 S	34 E	4125	Humble O. & G.			Abandoned
12	Lea........	6	20 S	38 E	4244	Leonard, Harry			Abandoned
13	Lea........	7	26 S	38 E	4030	Magnolia Petr. Co.			Abandoned
14	Lea........	32	10 S	34 E	4819	Maxwell, J. T.			Abandoned
15	Lea........	2	11 S	36 E	5162	Maxwell & Crandall			Abandoned
16	Lea........	30	17 S	34 E	4952	Phillips Petr.			Abandoned
17	Lea........	30	20 S	39 E	4711	Rushwold			Abandoned
18	Lea........	34	20 S	35 E	4195	Shell Oil			Abandoned
19	Lea........	1	18 S	34 E	4497	Texas Co.	600	3.	3½ miles south of Vacuum discovery well
20	Eddy......	13	24 S	26 E	2918	Collins, T. D.	Small well		Black River Dome area
21	Eddy......	35	18 S	31 E	3727	Shugart	Not completed		Swabbing and flowing 60 bbl. oil
22	Eddy......	20	30 S	30 E	1443	Wills, Neil	132		On swab

	In Proven Fields	Wildcats
Number of wells drilling Dec. 31, 1937..	83	32
Number of oil wells completed during 1937..	640	3
Number of gas wells completed during 1937..	19	0
Number of dry holes completed during 1937..	46	34

tion on the northwestern area, comprising San Juan and McKinley Counties. For information on the southeastern area, consisting of Eddy and Lea Counties, they are indebted to Mr. C. G. Staley, Proration Umpire for Lea and Eddy Counties, and his assistant, Mr. John Kelly. For general information and compilation of various data the assistance of Mr. T. P. Wootton, of the staff of the State Bureau of Mines and Mineral Resources, Socorro, is acknowledged.

Oil and Gas in New York in 1937

By D. H. Newland,* Member A.I.M.E., and C. A. Hartnagel†

Most of the petroleum produced in New York State is obtained by flooding; that is, water drive. No important oil fields have been developed during the past 30 years, nor does there seem much hope that the productive oil areas will be substantially enlarged in the future. There is some prospect that additional supplies may be obtained by deeper drilling, but deep tests for gas to the Oriskany sandstone in some of the oil-producing areas have been without results so far as any discoveries of oil are concerned.

Although the flooding method had been made legal in 1919, and some floods had been in operation previous to 1921, that year marks the beginning of a rapid increase in oil production by the new method. The flush production of oil in New York was in 1882, shortly after the discovery of the Richburg pool in Allegany County. The oil production in that year amounted to 6,685,000 bbl. The 1937 production of 5,478,000 bbl. was the largest since the flush production of 55 years ago. The effectiveness of water-flooding for increasing oil production from the old New York fields is shown in Table 1.

Table 1.—*Production of Oil in New York since* 1921

Year	Barrels	Year	Barrels
1921	988,000	1929	3,377,000
1922	1,000,000	1930	3,647,000
1923	1,250,000	1931	3,363,000
1924	1,440,000	1932	3,508,000
1925	1,695,000	1933	3,181,000
1926	2,242,000	1934	3,804,000
1927	2,603,000	1935	4,236,000
1928	3,377,000	1936	4,633,000
		1937	5,478,000

The area of the New York oil fields is about 60,000 acres. It has been estimated that not over one-fourth of the area is being flooded. Very little of flooded territory has ceased to produce. Some leases flooded by the early, less scientific methods are being again subjected to the water

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drive. The future life of the fields is dependent upon the size and number of floods. At present rate of production the supply will last 25 to 30 years. Even with a moderate increase in the number and size of the floods, large production can be maintained for at least 20 years, and at a declining rate for a period of 25 years.

GAS DEVELOPMENTS

In 1937 drilling operations for natural gas in New York resulted in an unusual increase in initial production. This account concerns only operations in relatively new territory and does not take into consideration the usual developments in the old, well established fields of the state. Most of the operations have been confined to the deeper sands in the southern tier of counties. There has been a marked falling off in the number of wells drilled in the Trenton limestone district and in shallow wells of the Medina sandstone. During the year 41 wells were completed, of which 28 are listed as commercial producers. The combined initial open-flow capacity of the wells was 403,418 M cu. ft. per day. Practically the entire new production was from the Oriskany sandstone in Steuben and Allegany Counties. At the close of the year 16 wells were being drilled.

Steuben County.—During 1937 the outstanding development in natural gas in New York State was the discovery in May of another gas pool in the Oriskany sandstone. The pool is in the town of Woodhull, Steuben County, where the discovery well, the Herrington, reached the top of the Oriskany at a depth of 3955 ft., and after penetrating the sand for a distance of 2 ft. developed a daily flow of 17 million cubic feet with a rock pressure of 1950 lb. Rapid development of the field followed and by the second week in January 1938 twenty wells (Table 2), all producers, had been completed. At present seven wells are being drilled. One of these is in the town of Troupsburg, southwest of the main group of wells, and if successful will extend the field in that direction.

The Woodhull pool as at present developed comprises an area about three miles long and two miles wide. The field has a general northeast-southwest direction and lies along the axis of Van Etten (Harrison) anticline. It is the only Oriskany gas field yet discovered on this structure in New York, but to the southwest in Pennsylvania are the following gas fields (the distances are from the Woodhull): Harrison, 16 miles; Ellisburg, 26 miles; Hebron, 32 miles. The Farmington and Tioga gas fields on the Sabinsville anticline in Pennsylvania are 12 and 16 miles, respectively, from the Woodhull field.

Previous to the discovery of gas in the Woodhull field, one unsuccessful deep test had been made along the southeast border—the Taft well, drilled in 1930. Starting at an elevation at 1500 ft., the top of the Oriskany was reached at 4042 ft. The Taft well proved to be low on the structure but is only ½ mile distant from one of the producing wells that was brought in with an initial daily flow of 12 million cubic feet. The thickness of the Oriskany in the Taft well was 14 ft. In the producing area only a few of the wells have penetrated the Oriskany more than 3 or 4 ft. Those drilled deeper in the Oriskany indicate a thickness of at least 14 ft. One well was completed 18 ft. below the top of the Oriskany, but the record does not indicate whether or not the entire interval is Oriskany.

TABLE 2.—*Productive Gas Wells in Woodhull Field*

Name of Well	Reported Operator	Elevation, Ft.	Depth to Oriskany, Ft.	Flow, M Cu. Ft.	Rock Pressure, Lb. per Sq. In.
Herrington	Atwater et al.	1,546	3,955	17,000	1,950
E. H. Ackerman	S. J. Brendel	1,773	4,123	12,438	1,912
Carrie Calkins	G. L. Cabot	1,604	4,020	20,000	1,915
C. Calkins	Becker	1,602	4,005	17,000	
H. Hand	Sylvania	1,743	3,987	22,200	1,945
Bates	Clancy et al.	1,396	3,856	14,000	1,910
E. Calkins	N. Y. State N. G.	1,680	4,025	26,000	1,940
Moyer	Hanley & Bird	1,595	3,943	27,000	1,895
A. H. Tuttle	Sylvania	1,452	3,882	25,500	1,945
R. A. Towsley	G. L. Cabot	1,591	3,905	28,000	1,930
C. Groves	G. L. Cabot	1,846	4,166	3,700	1,675
H. J. Tubbs	N. Y. State N. G.	1,488	3,864	10,480	1,875
L. S. Johnson	Belmont	1,636	4,029	8,000	
J. J. Johnson	Cunningham	1,632	3,977	6,000	1,680
J. Lobeck	Hanley & Bird	1,715	4,110	22,600	1,630
Fred Sly	J. Becker	1,715	4,071	20,000	1,600
E. H. Ackerman	Hanley & Bird	1,634	4,026	12,600	1,500
Earl Brown	Southwestern Dev.	1,591	3,972	15,000	1,440
Charles Finch	N. Y. State N. G.	1,760	4,019	19,500	1,710
C. L. Bonham	N. Y. State N. G.	1,745	3,987	5,000	

The dry Taft well at the southeast edge of the field probably marks its limit in that direction. On the other sides of the field no dry holes have yet been drilled and it is confidently expected that the field when fully developed will have an extent of approximately 6000 acres.

Southwest of the Woodhull field, two wells were completed near the Pennsylvania state line, in the town of Troupsburg. Both wells may be regarded as "step-out" wells of Harrison field of Pennsylvania. One of these, the Hendrickson well at an elevation of 2170 ft., reached the top of the Oriskany at 5106 ft. The well was reported completed with a daily flow of one million cubic feet and a rock pressure of 2160 lb. The Schaul well is ½ mile southwest of the Hendrickson at an elevation of 2058 ft. The top of the Oriskany was at 5010 ft. A flow of 796 M cu. ft. was found 9 ft. in the Oriskany with a rock pressure of 1935 lb.

The last report was that the well was being slightly deepened with the hope of increasing its gas flow.

In the town of Howard a well was drilled on the T. E. Moss property, at an elevation of 1845 ft., the top of the Oriskany being found at a depth of 3576 ft. The well was finished at 3600 ft. Ten feet of Oriskany was reported, which gave a daily flow of 200 M cu. ft. The Norman Phelps well in the town of Addison started at an elevation of 1347 ft. and reached the top of the Oriskany at 3820 ft. A daily flow of 20 M cu. ft. was found in the Oriskany, with a considerable amount of salt water.

One test well was drilled in the town of Jasper, 6 miles north-northwest of the Woodhull field, on the Bettinger farm, at an elevation of 1780 ft. The top of the Oriskany was reached at 4191 ft., but it contained only salt water.

In the town of Hartsville the Clara Lynch well was drilled from an elevation of 2288 ft. The Oriskany was found at a depth of 4715 ft. Drilling 4 ft. into the Oriskany resulted in a large flow of salt water.

In the Greenwood gas field two wells were drilled, one a producer and the other a dry hole. The successful well, the most southerly in the Greenwood field, is on the L. D. Clark farm, a few hundred feet south of the producing State well. The top of the well is at an elevation of 2264 ft. and the Oriskany was reached at 4758 ft. The well had an initial flow of 15 million cubic feet of gas and a rock pressure of 1760 lb. Two miles northeast of the Clark well an effort was made to extend the Greenwood field in that direction. A well on the Addie Coston (Wing) farm was started at an elevation of 1712 ft. The Oriskany was reached at a depth of 4179 ft. The Oriskany sandstone, 14 ft. thick, produced only salt water.

Allegany County.—In the State Line field four additional wells were completed during the year, three of which were producers. At the close of the year three wells were being drilled. One of the successful wells, the Lee Harder No. 2, is in the town of Alma. The well was drilled at an elevation of 2025 ft. and the Oriskany was reached at a depth of 4681 ft. The daily initial flow was 24 million cubic feet, with a rock pressure of 1540 lb. A second successful well, also in the town of Alma, is on the K. Mulvey farm. Drilling began at an elevation of 1999 ft., reaching the Oriskany at a depth of 4675 ft. The well had an initial flow of 22 million cubic feet and a rock pressure of 1400 pounds.

The F. Murphy well, also in the town of Alma, started at an elevation of 1971 ft. The Oriskany was reached at 4713 ft. The initial production was 8400 M cu. ft. with a rock pressure of 1110 pounds.

In the town of Willing only one test was completed. The Wilson well, 4 miles northeast of present production in the State Line field, started at an elevation of 2288 ft. The top of the Oriskany was reached at 4984 ft. but only salt water was present in the sand. Thus far in the

State Line field 35 wells, including two in the state of Pennsylvania, have been completed. Of these 24, all in New York, are present producers. Three gas wells, two of which produced considerable salt water with the gas at the time of completion, are no longer productive. Eight of the wells were salt-water wells when completed. Initial production of the wells in the State Line field ranged from 7500 M to 34,000 M cu. ft. daily, or an average flow per well of 24,000 M cubic feet.

A test well on the Terwilliger farm in the town of Angelica started at an elevation 2033 ft. and reached the Oriskany at a depth of 3987 ft. No gas was found in the Oriskany.

One Medina sandstone test was completed in the town of Allen, where previously nine wells had been drilled in search for gas in the Oriskany sandstone. The prevous tests of the Oriskany had resulted in relatively small flows of gas from some of the wells, but the presence of small amounts of a light-grade oil in the Oriskany was one of the incentives for further drilling. The Medina sandstone test was on the Platt (Bank of Angelica) farm, and drilling began at an elevation of 2005 ft. The top of the Oriskany was reached at a depth of 3380 ft. It proved to be only 4 ft. thick and unproductive. The well was then deepened. The top of the Niagara limestone was reached at 4413 ft. and the well-known "black water" of the Niagara at 4500 ft. The red Medina sandstone was reached at 4804 ft., with a showing of gas at 4917 ft. The well was completed as a dry hole at a depth of 5001 feet.

Cattaraugus County.—Two tests of the Medina sandstone were completed in the town of Leon. Five wells had previously been drilled in Leon, four of which were productive. One of the 1937 tests was on the Rideout farm. The top of the red Medina was reached at 3674 ft. and the bottom of the white Medina at 3807 ft. The well was abandoned at a depth of 3812 ft. without evidence of gas. The other Leon well was on the Hoffler farm. The top of the red Medina was found at a depth of 3599 ft. and the bottom of the white Medina at 3740 ft. The well was abandoned at a depth of 3745 ft. In the town of Randolph, on the H. Hotchkiss farm, a well was completed near three previously drilled wells that gave some promise that gas in commercial quantities might be found in the vicinity. The Hotchkiss well is reported as having reached the top of the red Medina at a depth of 4605 ft. The well was drilled to a depth of 4765 ft. and abandoned.

Schuyler County.—Southeast of the Wayne-Dundee gas field, in the town of Dix, three unsuccessful wells have been drilled as Oriskany tests. One well on the Shearer farm was drilled from an elevation 1270 ft. The Oriskany sandstone was found at a depth of 2284 ft., with a thickness of 13 ft. The well was completed at a depth of 2340 ft. The well on the Washburn farm was started at an elevation of 1108 ft. No Oriskany was found in the well but its horizon at the base of the Onondaga limestone was reached at 1986 ft. The bottom of the well is at 2142 ft. The well on the property of the Federal Land Bank found no Oriskany sand and the well is being deepened as a test of the lower Paleozoic formations. At the close of the year the well had reached a depth of more than 6400 ft. The top of the red Medina is recorded at a depth of 5298 feet.

Oneida County.—In this county, where 30 wells have been drilled since 1934, only one well was completed during the year—north of Utica in the town of Marcy, on the DeShane and Sequin farm. A small flow of gas was found in the upper part of the Trenton limestone. Salt water, however, entered the well, which was abandoned at a depth of 860 ft. In the Camden field, the village of Camden is being supplied with gas from the Trenton limestone. Gas from several of the wells drilled two or three years ago is being held in reserve and some of the wells now furnishing gas will be drilled deeper into the Trenton when the present production runs low.

Madison County.—Efforts to find gas in commercial amounts in the town of Brookfield are being continued. During the year one well was completed to the Medina, which was found at a depth of about 2000 ft. Small flows of gas were reported at several horizons in the well. Thus far four wells have been completed and one is being drilled near by at Pleasant Valley. One of the wells was drilled as a deep test. It reached a depth of 3642 ft. and was finished in the Little Falls (Cambrian) dolomite. A rock pressure of 600 lb. was recorded when the well was closed in, but the pressure rapidly declined as gas was withdrawn.

Oil and Gas Development in Ohio for 1937

By Dewitt T. Ring*

(New York Meeting, February, 1938)

Reliable and detailed data covering the enormous number of wells drilled and the long historical production of the state, many of which were never recorded until recent years, render it impossible to gather statistical material suitable for the Institute's standardized form.

The total production of crude oil in Ohio for the year was 3,654,503 bbl., which is less than the total production in the United States for the peak day of August 1937. For a period of eight years, from 1895 to 1902 inclusive, Ohio produced more oil than any other state. During the year, 1271 tests were drilled in the state, or 114 more than in 1936. Of these, 317 were oil wells, with an initial production of 7088 bbl., an average of 22.3 bbl. per well; 503 were gas wells, with an initial open flow of approximately 222,441 M cu. ft., or 443 M cu. ft. per gas well drilled; 451 were dry holes, that is, 35 per cent of the total completions.

A number of factors account for the steady decline of oil production in Ohio. In the state, at the close of the year, there were fewer than 28,122 producing oil wells. In 1936, there were 30,150 operated oil wells with an average yearly production per well of 126 bbl. The production for 1937 averaged 130 bbl. per well. During the year, 2028 oil wells were abandoned. In other words, old wells are being abandoned more than six times faster than new ones are being drilled.

Since the inception of the oil and gas industry in Ohio, between 150,000 and 160,000 wells have been drilled in the state; new potential territory, offering desirable locations for either oil or gas, is becoming increasingly more difficult to find; the dry-hole percentage will continue to increase.

PRICES

Another factor directly affecting the crude situation during the year was the matter of price and proration of Pennsylvania grade oil. The posted price for Pennsylvania grade in Ohio on June 7 was $2.37 per barrel; at the close of the year, it was $1.70 per barrel, or a reduction of 28 per cent in price. In addition to this price cut, a 50 per cent pro-

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ration, which still stands, was placed on this grade of oil in September. Ohio consumes more than 10 times as much as it produces from its 28,122 wells, averaging ⅓ bbl. per day. Proration was necessary on account of lost markets for Pennsylvania grade oil from Ohio; unless the economic side of the market situation is given relief for this grade of oil, Ohio in 1938 will drill fewer wells, produce less oil and abandon more wells than in 1937. The other two grades of oil produced in the state, namely Corning and Lima, are not prorated. Average daily productions of the three grades were as follows: Pennsylvania grade (9 months before proration), 4008 bbl.; Corning grade, 4000 bbl. (estimated); Lima grade, 2100 bbl.

Total production by grades for 1937 was as follows: Pennsylvania grade, 1,389,713 bbl.; Corning grade, 1,410,322 bbl.; Lima grade, 617,538 bbl.; Cleveland-Lodi grades, 102,088 bbl. Prices for crude oil in 1937 in Ohio were as shown in Table 1.

Table 1.—*Prices for Crude Oil in Ohio*

Date	Grade	Price per Bbl.	Date	Grade	Price per Bbl.
1937			1937		
Jan. 1–Feb. 24....	Pennsylvania	$2.12	Jan. 1–Jan. 29....	Corning	$1.32
Feb. 24–June 7....	Pennsylvania	2.22	Jan. 29–Sept. 2...	Corning	1.42
June 7–Sept. 1....	Pennsylvania	2.37	Sept. 2–Dec. 31...	Corning	1.27
Sept. 1–Oct. 12....	Pennsylvania	2.10	Jan. 1–Jan. 28....	Lima	1.15
Oct. 12–Dec. 1....	Pennsylvania	1.85	Jan. 28–Nov. 20..	Lima	1.25
Dec. 1–Dec. 31....	Pennsylvania	1.70	Nov. 20–Dec. 31..	Lima	1.00

Drilling

The Trenton field (also called Lima) in northwestern Ohio, comprising 15 counties, produces from the Trenton Lime; the oil is classified as Lima grade. During the year, 74 tests were drilled in this territory, 44 of which were completed as oil wells with a total initial production of 1280 bbl.; 20 dry holes were drilled and 11 small gas wells completed.

In the central and southeastern Ohio fields, the Clinton, Oriskany, Berea, Big Injun, and shallower sands furnish the production. The Clinton sand alone accounts for approximately 80 per cent of the gas production in the state, as well as a good part of the oil production.

New Development

No outstanding discoveries that might indicate any new fields were made during the year; in most instances, they were extensions to present producing oil areas. The more important were as follows:

Knox County.—In Jackson township, nine Clinton sand wells, with initial productions ranging from 45 to 207 bbl. of Corning grade oil, were completed with an average depth of 3175 ft. In Union township, five Clinton sand wells with initial productions ranging from 5 to 175 bbl. of Corning grade oil were completed; average depth, 2835 ft. In Butler township, a new Clinton sand gas field is being developed with wells ranging from less than one-half million to 7½ million cubic feet open flow. Rock pressures are slightly under normal; average depth 3000 feet.

Perry County.—In Clayton township, six Clinton oil wells with average initial production of 130 bbl. per well. Five of these wells were not shot on account of reduced allowable. The oil is Pennsylvania grade. This is a new field. The average depth is 3275 feet.

Tuscarawas County.—In Lawrence and Franklin townships, indications point to a new Clinton sand gas field. Open flows range from 150 to 8283 M cu. ft. Six wells have been completed, the depths averaging from 4500 to 4700 feet.

TABLE 2.—*Wells in Lima Fields*

County	Number of Completions	Number of Oil Wells	Production of Oil, Bbl.	Number of Gas Wells	Production of Gas, M Cu. Ft.	Number of Dry Holes
Allen	1	1	12	0	0	0
Auglaize	2	0	0	0	0	2
Fulton	1	0	0	0	0	1
Hancock	11	8	96	0	0	3
Hardin	3	1	35	1	5	1
Henry	6	5	76	0	0	1
Mercer	2	1	15	0	0	1
Ottawa	2	0	0	2	326	0
Putnam	16	16	787	0	0	0
Sandusky	4	2	7	0	0	2
Seneca	18	7	226	7	221	4
Shelby	2	0	0	1	?	1
Wood	2	0	0	0	0	2
Wyandot	5	3	28	0	0	2
Total 1937	75	44	1282	11	552	20
Total 1936	81	35	476	37		9
Difference	− 6	+ 9	+ 806	−26		+11

REPRESSURING PROJECTS

No new Clinton sand repressuring projects were started during the year. Two such projects have been in operation for the past three years, and are functioning satisfactorily. Both are operated with natural gas. The Chartiers Oil Company's project is in Coal township, Perry County. The depth of the wells ranges from 3200 to 3400 ft. The combined weekly production (eight wells) at the beginning of the

TABLE 3.—*Summary of Wells Completed in* 1937, *Central and Southeastern Ohio Fields*

County	Number of Completions	Number of Oil Wells	Production of Oil, Bbl.	Number of Gas Wells	Production of Gas, M Cu. Ft.	Number of Dry Holes
Ashland	24	3	33	12	14,732	9
Ashtabula	5	0	0	2	60	3
Athens	81	14	55	36	7,515	31
Belmont	39	7	24	16	8,596	16
Carroll	16	4	11	3	250	9
Columbiana	29	3	8	9	1,058	17
Coshocton	17	9	559	2	837	6
Cuyahoga	7	1	16	5	1,416	1
Delaware	1	0	0	0	0	1
Fairfield	15	0	0	11	1,421	4
Gallia	1	0	0	1	42	0
Guernsey	82	0	0	44	9,332	38
Harrison	4	0	0	0	0	4
Hocking	20	8	225	6	1,163	6
Holmes	17	1	37	9	3,883	7
Huron	27	0	0	25	7,641	2
Jefferson	28	7	11	8	7,014	13
Knox	58	19	1,489	22	18,767	17
Lawrence	4	0	0	4	1,038	0
Licking	88	54	1,250	15	1,083	19
Lorain	31	0	0	19	12,237	12
Mahoning	7	3	?	1	?	3
Medina	63	30	209	9	7,116	24
Meigs	95	4	8	57	18,929	34
Monroe	41	14	32	18	3,649	9
Morgan	42	13	24	18	4,949	11
Muskingum	43	18	936	8	11,774	17
Noble	36	6	10	16	1,722	14
Perry	52	15	713	20	8,013	17
Portage	2	0	0	0	0	2
Richland	2	0	0	0	0	2
Scioto	2	0	0	0	0	2
Stark	48	0	0	41	40,859	7
Summit	16	0	0	11	13,391	5
Trumbull	2	0	0	0	0	2
Tuscarawas	21	0	0	11	9,811	10
Vinton	12	4	15	6	349	2
Washington	105	36	142	24	2,862	45
Wayne	13	0	0	3	380	10
Total	1,196	273	5,807	492	221,889	431
Total Lima	75	44	1,282	11	552	20
Grand total 1937	1,271	317	7,089	503	222,441	451
Grand total 1936	1,157	263	6,631	570		324
Difference	+ 114	+ 54	+ 458	− 67		+127

experiment was 20 bbl. At the end of a 12-month period, it had been increased to an average of 250 bbl. per week. The project is now three years old.

TABLE 4.—*Summary of Holes Drilled in Ohio in* 1937, *Exclusive of Deepening Operations*

Sand	Feet Drilled	Number of Gas Wells	Percentage of Total	Number of Oil Wells	Percentage of Total	Number of Dry Holes	Percentage of Total
Shallow	305	115	38	73	24	117	38
Berea	465	167	36	119	26	179	38
Shale	27	22	82	0	0	5	18
Lime	20	17	85	2	10	1	5
Austinburg	5	2	40	0	0	3	60
Oriskany	6	2	33	0	0	4	67
Newburg	2	1	50	0	0	1	50
Clinton	364	166	45	79	22	119	33
Trenton	74	11	14	44	61	19	25
St. Peter	3	0	0	0	0	3	100
Total	1,271	503	40	317	25	451	35

The Preston Oil Co. began a similar experiment in 1936, in Starr township, Hocking County, and it is operating successfully at the present time. Twenty-three wells are involved in this project.

TABLE 5.—*Initial Volumes*

Sand	Total Initial Volume		Average Initial Volume	
	M Cu. Ft.	Bbl.	M Cu. Ft.	Bbl.
Shallow	41,546	221	361	3
Berea	30,135	610	186	5
Shale	5,111		464	
Lime	5,156	13	303	6.5
Austinburg	60		30	
Oriskany	905		452	
Newburg	800		800	
Clinton	138,176	4,963	832	63
Trenton	552	1,282	55	30
Total	222,441	7,089	443	22

GEOPHYSICAL WORK

Considerable seismic work was done in the southeastern portion of the state during the year, particularly in Washington, Noble, Meigs, Athens and Morgan Counties. This was largely brought about by the present Oriskany sand development in West Virginia. Two or three interesting wildcat tests will be drilled in the Ohio Valley during 1938 in an effort to locate the western margin of the Oriskany sand.

TABLE 6.—*Total Production of Oil in Ohio*
THOUSANDS OF BARRELS

Year	Production	Year	Production	Year	Production
1876	32	1897	21,561	1918	7,368
1877	30	1898	18,739	1919	7,736
1878	38	1899	21,142	1920	7,400
1879	29	1900	22,363	1921	7,335
1880	39	1901	21,648	1922	6,781
1881	34	1902	21,014	1923	7,085
1882	40	1903	20,480	1924	6,811
1883	47	1904	18,877	1925	7,212
1884	90	1905	16,347	1926	7,272
1885	662	1906	14,788	1927	7,593
1886	1,782	1907	12,207	1928	7,015
1887	5,023	1908	10,859	1929	6,743
1888	10,011	1909	10,663	1930	6,519
1889	12,472	1910	9,916	1931	5,327
1890	16,125	1911	8,817	1932	4,644
1891	17,740	1912	8,969	1933	4,264
1892	16,363	1913	8,781	1934	4,234
1893	16,249	1914	8,536	1935	4,070
1894	16,792	1915	7,825	1936	3,791
1895	19,545	1916	7,744	1937	3,654
1896	23,941	1917	7,751		

PRE-CAMBRIAN TESTS

Two tests were abandoned during the year in the pre-Cambrian rocks; one in sec. 3, Orange township, Delaware County, was bottomed at 4291 ft., presumably about 350 ft. in pre-Cambrian material. The other test is in sec. 2, Peru township, Huron County, and reached a depth of 4270 ft. Preliminary examination of cuttings indicates probably 100 ft. of pre-Cambrian.

ACKNOWLEDGMENTS

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Petroleum Development in Oklahoma in 1937

By H. E. Rorschach*

(New York Meeting, February, 1938)

Activity in Oklahoma oil fields made 1937 one of the best years since 1926. During the year, 3454 wells were completed, an increase of about 25 per cent over the year 1936. Purchasers' reports filed with the Corporation Commission of the State of Oklahoma showed a total of 221,842,788 bbl. of oil purchased from leases in 1937, an increase of about 10 per cent over 1936. The assembly of a complete table of all of the oil fields in Oklahoma has not yet been achieved. Many of the early records of operators and pipe-line companies are incomplete. Table 1 includes all of the new fields, and this year there has been added work done covering pools discovered in previous years, so that most of the important fields in the state of Oklahoma are included therein.

The outstanding development of the year was the discovery of the producing horizon classified as the Wilcox in western Payne County by the Mid-Continent Petroleum Corporation on a unitized block in sec. 18, Tp. 18 N., R. 2 E. This block is operated by the Mid-Continent and owned in conjunction with the Carter Oil Co., Transwestern Oil Co. and Sinclair-Prairie Oil Co. Another important development of the year was the extension of the deep zone in the old Fox-Milroy area of Carter and Stephens Counties.

Some of the other discoveries made during the year 1937 are South Cromwell, discovered by Sinclair-Prairie Oil Co.; Cromwell extension of the Fitts pool in Pontotoc County; discovery of the Langston area in Logan County; discovery of the Sporn area in Lincoln County by Skelly Oil Co. and the discovery of the North Wellston area in Lincoln County by Standard Oil & Gas Co. Table 2 shows the new oil areas discovered in Oklahoma during the year 1937 and areas that were discovered in 1936 but developed in 1937.

Fox-Milroy Area.—Three wells were completed to the deep producing zone during the year. One of the wells completed in the early part of the year was the Carter Oil Company's No. 1 Harley in sec. 24, Tp. 2 S., R. 4 W., 3½ miles northwest of the original discovery well, the Ruth

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Williams No. 1, completed June 2, 1936, by the Carter Oil Co. in sec. 27, Tp. 2 S., R. 3 W. The Gulf completed two wells in the latter part of the year, No. 1 Johnson in sec. 27, Tp. 2 S., R. 3 W., and No. 1 Smith in sec. 26, Tp. 2 S., R. 3 W. The discovery well, No. 1 Ruth Williams, produced approximately 364,000 bbl. up to the end of 1937.

At the end of the year, Gulf Oil Corporation was commencing operations on several wells in secs. 27 and 28, Tp. 2 S., R. 3 W., which were started for the deep zone. Carter Oil Co. had announced a new location for the deep zone in sec. 36 and the Wirt Franklin Petroleum Corporation had announced one for sec. 27.

It appears that the year 1938 should see the definition of an additional area of this deep zone. A map of the area is shown on Fig. 1.

Fitts Pool.—The Fitts area, Pontotoc County, was extended during the year, and two producing horizons, the Cromwell and Gilcrease, assumed considerable importance during the year 1937.

Moore Pool.—The Moore pool, Cleveland County, opened by the Sinclair-Prairie, saw continued activity. Bottom-hole pressures declined at the end of the year to about 900-lb. pressure.

Oklahoma City Pool.—The Oklahoma City pool saw the completion and outlining of the north part of the pool. Bottom-hole pressures have declined to the point where most of the wells in the capitol extension area are being produced by submersible electric centrifugal pumps or by gas lift and many wells have had to be pumped on the beam by using the conventional rods and tubing. Pawhuska lime and Tonkawa sand production has been opened up in the south part of the field. Many of the exhausted deep wells will be plugged back to the upper horizons and attempts made to produce from these zones during the year 1938.

Jesse Pool.—The Jesse pool, Pontotoc County, continued to be developed further, with several large producers completed during the year 1937.

Greater Seminole Area.—Production increased in many of the pools of the Greater Seminole area, owing to the removal of proration in the middle of the year. New areas were developed in the general Seminole district during the year, the Traugh Sonora sand; the Traugh deep sand; the East Shawnee and the North Shawnee district and some production was secured in the Tecumseh area. Sinclair-Prairie opened an extension to the Cromwell pool, which was termed the South Cromwell. Several small pools have been opened in the general Seminole area in the upper zones that lie above the Wilcox.

Southern Oklahoma.—During the year, the Indian Territory Illuminating Oil Co. opened the Frederick and Frederick-Hattler area in Tillman County. A deep zone in the Doyle pool was opened by Helmerich & Payne in the early part of the year. This was an old, shallow pool, which has produced some oil and gas from upper horizons. During the year, a

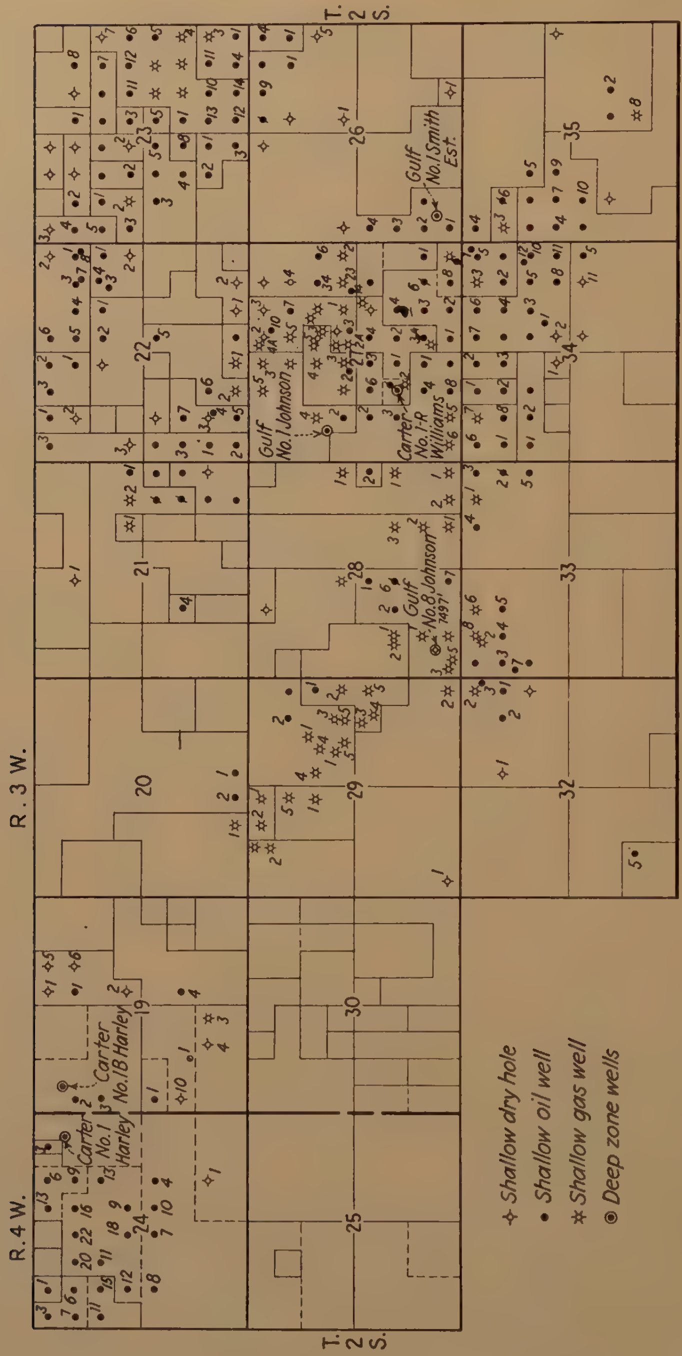

FIG. 1.—FOX AREA, OKLAHOMA.

TABLE 1.—*Oil and Gas Production in Oklahoma in* 1937

Line Number	Field, *County*	Age, Years to End of 1937	Area Proved, Acres				Total Oil Production, Bbl.	
			Oil	Oil and Gas[a]	Gas	Total	To End of 1937	During 1936
1	Adams, *Hughes*	2	200			200	249,196	64,846
2	Allen and West Allen, *Pontotoc*	24	300			300	42,003,601	2,812,947
3	Altusi, *Jackson*	4	490			490		182,500
4	Asher-Wanette, *Pottawatomie*	8	675			675	6,845,259	193,220
5	Bethel, *Seminole*	14	570			570		43,680
6	Bethel, North, *Seminole*	1⅓	320			320	981,714	16,671
7	Billings, *Noble*	22	600		60	600		*y*
8	Billings-Wilcox, *Noble*	2					2,439,028	141,362
9	Binger, *Caddo*	4	10			10	26,906	9,739
10	Bowlegs, *Seminole*	11	3,820			3,820	108,043,166	4,319,663
11	Braman, North and South, *Kay*	14	910	185		1,095		*y*
12	Britton, North, *Oklahoma*	3	100			100	341,143	150,315
13	Britton, South, *Oklahoma*	3	250			250	1,181,490	595,323
14	Brock, *Carter*	16	600			600	3,896,000	150,000
15	Burbank, *Osage, Kay*	17	22,210		230	22,440	10,038,800	2,829,000
16	Caldwell, *Grant*	9	30			30		*y*
17	Carr City, *Seminole*	10	1,060			1,060	27,209,644	2,205,001
18	Carter-Knox, *Grady-Stephens*	13	1,880		250	2,130	12,431,000	534,000
19	Cement, *Caddo*	21						621,198
20	Chandler, *Lincoln*	13	1,160			1,160	1,719,299	*y*
21	Cleveland, *Pawnee*	34	9,720			9,720		654,559
22	Crescent, *Logan*	5	1,010			1,010	9,215,091	2,233,414
23	Cromwell, *Seminole*	15	4,790		130	4,920	52,809,000	1,330,000
24	Cushing, *Creek*	26	23,528			23,528		4,085,879
25	Davenport, *Lincoln*	12		2,000		2,000		*y*
26	Deep Rock, *Payne*	13	520		80	600		*y*
27	Dill, *Okfuskee*	4	640			640	1,423,808	578,800
28	Dilworth, *Kay*	23	5,280		2,720	8,000		*y*
29	Earlsboro, *Pottawatomie, Seminole*	12	4,730			4,730	121,143,634	2,305,594
30	Earlsboro, East, *Seminole*	9	2,000			2,000	35,537,718	1,338,492
31	Earlsboro, North: Hunton, *Seminole*	2	160			160	163,966	70,441
32	Wilcox, *Seminole*	1½	280			280	537,850	53,132
33	Earlsboro, South, *Seminole*	8	300			300	8,117,417	226,000
34	Edmond, *Oklahoma*	8	1,040	80	20	1,140	11,630,779	4,386,440
35	Fairfax, *Osage*	12	*y*			*y*	*y*	*y*
36	Fitts: Upper Simpson, Hunton, Wilcox, Gilcrease, and Cromwell Sands, *Pontotoc*	4	4,230				57,517,334	19,760,537
37	Fitts, Oil Creek, *Pontotoc*	2	10				54,600	18,660
38	South Fitts, *Pontotoc*	¾	320			320	63,603	None
39	West Fitts, *Pontotoc*	½	170			170	20,608	None
40	Fox, *Carter*	22	1,110		420	1,530		350,000
41	Fox-Simpson, *Carter*	3	80			80	252,964	81,000
42	Garber, *Garfield*	22	3,840			3,840	*y*	708,038
43	Gessman, *Lincoln*	4	110			110		*y*
44	Glenn, *Creek*	33	14,720*y*	*y*	*y*	14,720*y*	*y*	*y*
45	Graham, *Carter*	20	2,520		220	2,740	*y*	600,000
46	Gray, *Pottawatomie*	6	180			180	922,082	560,000
47	Grayson, *Seminole*	3	130			130	690,078	261,574
48	Grisso, *Pottawatomie*	4				80	*y*	66,200
49	Healdton, *Carter*	24	8,100			8,100	177,682,000	3,449,000
50	Hewitt, *Carter*	19	3,450			3,450	83,414,000	1,644,000
51	Hominy, *Osage*	18	300			300	*y*	30,499
52	Hominy, East, *Osage*	17	450			450	*y*	28,423
53	Hoyt, *Lincoln*	3	*y*			*y*	780,830	330,359
54	Hubbard, *Kay*	14	620			620		*y*
55	Hull, *Logan*	4	80			80	*y*	33,771
56	Jesse, *Pontotoc*	3	1,360			1,360	1,440,480	401,912
57	Josey, *Okfuskee*	15		300	10	310	*y*	*y*
58	Keokuk Falls, *Seminole*	5	2,300			2,300	6,180,201	2,089,000
59	Keokuk Falls-Hunton, *Pottawatomie*	3					291,388	51,231
60	Laffoon, *Lincoln*	5	60			60	945,000	320,000
61	Langston, *Logan*	4	300			300	413,579	55,000
62	Lincreek, *Lincoln-Creek*	22	160			160		*y*
63	Little River, *Seminole* and	11	5,540			5,540	116,360,055	5,016,042
64	Little River, East, *Seminole*	10						
65	Lovell, West, *Logan*	2	20			20	89,520	39,388

[a] Footnotes to column heads and explanation of symbols are given on page 313.

TABLE 1.—(*Continued*)

Line Number	Total Oil Production, Bbl.		Total Gas Production, Millions Cu. Ft.				Number of Oil and/or Gas Wells							
								During 1937		At End of 1937				
	During 1937	Daily Average during Nov., 1937	To End of 1937	During 1936	During 1937	Maximum Daily during 1937	Completed to End of 1937	Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Oil and Gas[b]	Producing Gas Only	Total Producing
1	184,350	873					10	6			10			10
2	2,134,688	5,302									261			
3														
4	153,538	364									40			
5														
6	965,043	2,539					30	29			30			30
7														
8	2,296,789	7,086									59			
9											1			
10	4,153,084	10,985									242			
11														
12	180,590	369									9			
13	537,105	824									18			
14	125,000										121			121
15	5,274,855	12,639	y	x	y	y	2,204	4	11		1,928			1,928
16														
17	1,951,376	4,912	26,977,000			4,900	100				89			89
18	546,000	1,528		x			225	1	1		143			
19														
20	684,406	1,461									51			
21														
22	3,757,172	8,198												
23	1,262,674	3,435		x			492	1			271			
24														
25														
26														
27	633,131	1,554									20			
28														
29	2,227,871	6,183									213			
30	1,378,882	3,542					y	y	y	y	104			104
31	94,299	159					5	1			5			
32	485,057	2,123					28	20			28			28
33	276,496	721					30				21			
34	5,674,134	9,655					100	26		y	97		1	98
35	y	y					y	y						y
36														
	30,622,825	77,011												
37	35,940	100									1			1
38	63,603	243									11			
39	63,603	y									7			
40			y	2,500	y	y	144				98		33	131
41	162,736	445		0			2	1			2			2
42	y	y					873				582		x	582
43														
44	y	y	y	y	y	y	y	y	y	y	y	y	y	y
45	y			1,000										
46	433,633	1,148					24	2			24			
47	182,915	442									12			
48	y	y												
49	3,620,000	9,544		x			2,276	75	29		1,937			1,937
50	1,582,000	4,246		x			908	6	23		779			779
51	y	y					y	y			y			y
52	y	y												
53	392,014	994									14			
54	y	y												
55	y	y												
56	1,020,154	2,449									30			30
57	y	y												
58	2,712,921	6,587	y	0	y	y	106	6			91		15	106
59	229,229	481									13			
60	250,000													
61	220,370	876	y	y	y	y	12	9			12			
62														
63	4,088,162	10,051									336			
64														
65	40,132	54									2			

TABLE 1.—(*Continued*)

Line Number	Depth, Average in Feet		Oil Production Methods at End of 1937		Pressure, Lb. per Sq. In.^{d}			Character of Oil, Approx. Average during 1937				
			Number of Wells			Average at End of		Gravity A.P.I. at 60° F.				
	Bottoms of Productive Wells	To Top of Productive Zone	Flowing	Pumping	Initial	1936	1937	Maximum	Minimum	Weighted Average	Sulphur, Per Cent	Base^e
1			8	2	e1,500					40		M
2					*y*	*y*				30		*y*
3					*y*	*y*				43		*y*
4					*y*	*x*				43		*y*
5								40	32	36	0.2	M
6	3,615	3,630	22	8	1,300	1,300				40		M
7					*y*	*y*				41		*y*
8					e1,740	e1,720					*y*	*y*
9					*y*	*y*				41		*y*
10					*y*	*y*				40	*y*	*y*
11					*y*	*y*				41	*y*	*y*
12					2,000	*y*				43	*y*	*y*
13					2,200	*y*				43	*y*	*y*
14	2,100							38	25	35	0.8	A
15	2,850	2,700			*x*	*x*		*x*	*x*	38	*x*	P
16					*y*	*y*				44	*y*	*y*
17	4,205	4,180		89	e320	*x*		*y*	*y*	40	0.3	M
18	2,200	1,700		143	*x*	*x*		38	26	35	*x*	*x*
19					*y*	*y*				35	*y*	*y*
20					*y*	*y*				40	*y*	*y*
21					*y*	*y*				37	*y*	*y*
22					e2,920	*y*				42	*y*	*y*
23	3,400			271	*x*	*x*				35	*x*	*x*
24					*y*	*y*				40	*y*	*y*
25					*y*	*y*				46	*y*	*y*
26					*y*	*y*		*y*	*y*	*y*	*y*	*y*
27					*y*	*y*				40	*y*	*y*
28					*y*	*y*				40	*y*	*y*
29					*y*	*y*				39	*y*	*y*
30	*y*	*y*			*y*	*y*				39	*y*	*y*
31					e1,940	e1,900				40		M
32	4,650	4,640		28	e1,385	e1,365				31		M
33	4,225	4,200		21	e500	e350				40	0.3	M
34	*y*	*y*			e2,900	e1,900		52	38	39	*y*	P
35					*y*	*y*				38	*y*	*y*
36												
37					*x*	*x*				37.9	*y*	*y*
38												
39												
40	2,500	2,200			500–2,900	*y*		46	27	*y*	*y*	M
41	8,037	7,950	2		*x*	*x*				30	*x*	*x*
42	4,200	1,100			*y*	*y*				44	*y*	*y*
43					*y*	*y*				45	*y*	*y*
44	*y*	*y*	*y*	*y*	*y*	*y*	*y*			35	*x*	P
45					750	*y*		36	26	32	*y*	M
46	3,475	2,500		24	e1,440	*x*				40	*x*	M
47					*y*	*y*				40	*y*	*y*
48	4,050	4,030								35	*x*	M
49	1,500			1,937	*x*	*x*		32	29	31	*x*	*x*
50	1,700	*y*		779	*x*	*x*		36	31	34	*x*	*x*
51	2,685	2,625			*y*	*y*		41		37	*y*	*y*
52	2,210	2,160			*y*	*y*		36		34	*y*	*y*
53	5,100	*y*			*y*	*y*				41	*y*	*y*
54	*y*	*y*			*y*	*y*				39	*y*	*y*
55	4,800	*y*			*y*	*y*				42	*y*	*y*
56	4,633	4,621			*y*	*y*				41	*y*	*y*
57	3,650	3,600			*y*	*y*				41	*y*	*y*
58	4,152	4,117			1,828	1,400		41.6	39.4	40	*x*	*x*
59					*y*	*y*				41	*y*	*y*
60	4,275	4,190			e1,872	e275				22.5	*x*	A
61	5,145	5,100	9	3	*x*	*y*		*x*	*x*	40	*x*	M
62					*y*	*y*				32	*y*	*y*
63					*y*	*y*				39	*y*	*y*
64					*y*	*y*				36	*y*	*y*
65					*y*	*y*				40	*y*	*y*

TABLE 1.—(*Continued*)

Line Number	Producing Rock						Number of Dry and/or Near-dry Holes to End of 1937	Deepest Zone Tested to End of 1937	
	Name	Age[f]	Character[g]	Porosity[h]	Net Thickness, Average in Feet	Structure[i]		Name	Depth of Hole, Ft.
1	Hunton-Misener	Sil-Mis	Lime S	P	15	A		Wilcox	4,317
2	Cromwell-Wilcox	Pen-Ord	S	Por	y	AF		y	y
3	Granite wash	Pen	S	Por	30	D			
4	y	y	y	y	y	y			
5	Booch	Pen	S	silty	27y	ML			
6	Cromwell	Pen	S	Por	20	A	2	Cromwell	
7	Hoover	Pen	S	Por	50	A			
8	Wilcox	Ord	S	Por		A			
9	Binger	Pen	S	Por	y	y			
10	Wilcox or Simpson	Ord	S	Por	30	A			
11	Various	Pen-Ord	SL	Por	y	A			
12	Simpson	Ord	D, L	Por		A			
13	Simpson	Ord	D, L	Por	50	AF			
14	Various	Pen	S	Por		AF		Ord lime	3,000
15	Burbank	Pen	S	Por	60	ML		Granite	4,240
16	Wilcox	Ord	S	Por	6	A			
17	Hunton-Wilcox	Pen-Ord	L-S	Por	x	A		Wilcox	4,210
18	Various	Per	S	15–20	15	AF			8,963
19	Caddo, Fortuna	Per-Pen	S	y	y	y			
20	Wilcox	Ord	S	Por	x	A			
21	Cleveland-Bartlesville	Pen	S	Por	y	y			
22	Layton-2nd Wilcox	Pen-Ord	S	23	y	AF			
23	Cromwell	Pen	S	Por	x	AF		Wilcox	4,226
24	Numerous Horizons	Pen-Ord	S, L	Por	x	AF			
25	Prue	Pen	S	Por	50	ML			
26	Wilcox, Bartlesville	Pen-Ord	S	Por	50	A			
27	Hunton-Cromwell	Sil, Pen	S, L	Por	30	y			
28	Various	Ord, Per, Pen	S, SL	Por	y	A			
29	Earlsboro-Wilcox	Pen-Ord	y	y	y	y			
30	y	y	y	y	y	y		y	y
31	Hunton	Sil	L			A		Wilcox	4,680
32	Wilcox	Ord	S	Por	10	A		Wilcox	4,680
33	Wilcox	Ord	S	Por	25	A		Wilcox	4,225
34	Wilcox	Ord	S	Por	y	AF		Arbuckle	7,000
35	Burbank	Pen	S	20–25	y	ML			
36									
37	Oil Creek	Ord	S	Por	10	AF			
38	Bromide	Ord	S	Por					
39	Cromwell	Pen	S	Por					
40	Deese	Pen	S	30	x	A			
41	Simpson	Ord	S	x	x	AF		Simpson	8,105
42	Various	Per-Pen-Ord	S, L	Por	y	AF		y	y
43	Cleveland	Pen	S	Por	y	M			
44	Glenn, Wilcox	Pen-Ord	S	Por	y	ML	y	Arbuckle	2,964
45	Deese	Lower Pen	S	28–30	45–70	A		Dornicks Hills	5,180
46	Wilcox	Ord	S	Por	25	A		Wilcox	3,500
47	Hunton, Simpson dolomite	Sil, Ord	SL	y	y	y		y	y
48	Hunton	Sil	L	x	x	A		Wilcox	4,860
49	Various	Pen-Ord	SL	Por	x	AF		Arbuckle	x
50	Hoxbar	Pen	S	15–20	50	AF		Arbuckle	x
51	Burgen-Siliceous lime	Ord	S, D	x	50	A		Arbuckle	3,206
52	Bartlesville	Pen	S	x	y	A		Arbuckle	2,857
53	1st Wilcox	Ord	S	Por	y	y		y	y
54	Various	Pen-Ord	SL	Por	y	AF		y	y
55	Layton	Pen	S	Por	y	y		y	y
56	McLish	Ord	S	Por	y	AF		y	y
57	Wilcox	Ord	S	x	50	D		Wilcox	3,700
58	Misener-Hunton	Mis, Sil	SL	y	15–20	A		Wilcox	4,483
59	Hunton	Sil	L	y	y	y			
60	Wilcox	Ord	S	Por	x	A		Wilcox	
61	Wilcox	Ord	S	Por	x	A	1	Wilcox	5,194
62	Wilcox	Ord	S	Por	y	y			
63	y	y	y	y	y	y			
64	Cromwell-Wilcox	Pen, Ord	S	Por	y	y			
65	Wilcox	Ord	S	Por	y	y			

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Age, Years to End of 1937	Area Proved, Acres				Total Oil Production, Bbl.	
			Oil	Oil and Gas[a]	Gas	Total	To End of 1937	During 1936
	Lucien, *Noble*							
66	East: Misener	3	10			10	109,864	36,618
67	Viola	3	10			10	121,527	36,472
68	North	2	160			160	145,005	10,436
69	Lucien	5	2,660			2,660	16,888,278	4,401,926
70	Marshall, *Logan*	11	700	240		940		*y*
71	Maud, *Pottawatomie-Seminole*	9	1,440			1,440	10,806,230	340,000
72	Meeker, *Lincoln*	3	10			10		None
73	Mission, *Seminole*	11					23,372,490	888,860
74	Moore, *Cleveland*	3	1,060			1,060	4,175,280	441,048
75	Naval Reserve, *Osage*	10	2,720		160	2,880	4,500,748	2,708,014
76	Nicoma Park, *Oklahoma*	8					310,420	20,998
	Oklahoma City, *Oklahoma*							
77	Wilcox	8	6,900			6,900	285,933,861	42,688,205
78	Lower Simpson	9	10,000			10,000	96,883,978	8,044,564
79	Cleveland	9	80			80	1,376,409	537,751
80	Other Zones	9	570	1,020		1,590	19,857,840	80,202
81	Upper Simpson	5	10			10	841,364	45,768
82	Olympic, *Hughes, Okfuskee*	4	4,400			4,400	6,005,958	2,795,408
83	North Olympic, *Hughes, Okfuskee*	1					1,077,340	13,151
84	Otoe City, *Noble*	7	10			10		*y*
85	Ostott, *Kay*	20	3,300			3,300		*y*
86	Papoose, *Hughes, Okfuskee*	14	2,400			2,400		350,000
87	Pettit, *Osage*	18	380			380		*y*
88	Polo, *Noble*	4	390			390	2,722,168	1,041,611
89	Ponca City, *Kay*	27	1,670			1,670		*y*
90	Ripley North, *Payne*	10		90		90		*y*
91	Robberson, *Garvin*	17	1,480		320	1,800		500,000
92	St. Louis, *Pottawatomie-Seminole*	12	7,300			7,300	111,235,674	8,343,313
93	Sasakwa, *Seminole*	10	560			560	7,627,549	426,292
94	East Wilcox	3					668,249	303,483
95	Townsite	5	120			120	1,797,982	308,727
96	Searight	12	1,300			1,300	32,321,159	829,194
97	Searight, North, *Seminole*	4	310			310	2,058,858	908,337
98	Seminole, *Seminole*	12	4,150			4,150	124,600,000	4,857,929
99	Seminole, West, *Seminole*	8	260			260	10,675,289	2,048,000
100	Shawnee, *Pottawatomie*	4	640			640	828,153	209,510
101	Sholom Alechem, *Carter-Stephens*	14	4,180		220	4,400		1,273,000
102	Stillwater, *Payne*	3	120			120	410,695	270,000
103	Tatum, *Carter*	11	2,230			2,230	*y*	1,280,000
104	Thomas, *Kay*	14	140			140	*y*	*y*
105	Tipton, *Jackson*	3	330			330	*y*	*y*
106	Tipton-Arbuckle, *Jackson*	2	280			280	*y*	211,180
107	Tonkawa, *Kay, Noble*	17	2,300			2,300	*y*	*y*
108	Tussy, *Garvin*	5	360			360	*y*	231,000
109	Vernon, *Kay*	14	920			920	*y*	*y*
110	Vines, *Murray*	18					*y*	*y*
111	Watchorn, *Pawnee*	22	320			320	*y*	*y*
112	Wewoka and Wewoka Townsite, *Seminole*	15	2,150			2,150	*y*	
113	Wheeler, *Carter*	22	540		160	700	*y*	39,000
114	Wilzetta, *Lincoln*	4	200			200	563,000	145,000
115	Zimmerman, *Lincoln*	2	40			40		*y*
116	Marathon, *Noble*	3						31,660
117	Dora, *Seminole*	1	760			760	451,041	
118	Fish-Cromwell, *Hughes, Seminole*	8					5,185,535	976,843
119	Fish-Wilcox, *Hughes, Seminole*	4					4,471,648	1,888,844
120	Milroy-Deep, *Stephens*	⅓	10			10	93,552	None
121	Shawnee-East, *Pottowatomie*	½	10			10	12,862	None
122	Shawnee-North, *Pottowatomie*	⅓	10			10	26,316	None
123	Sporn, *Lincoln*	1	90			90	214,181	None
124	Tecumseh, *Pottowatomie*	½	10			10	26,051	None
125	Traugh, Deep, *Seminole*	⅓	190			190	23,863	None
126	Traugh, Shallow, *Seminole*	1	340			340	297,172	None
127	Wellston-North, *Lincoln*	2	490			490	388,245	6,422
128	Jesse Hunton, *Pontotoc*	4	110			110	170,292	
129	Konawa, *Seminole*	8					13,265,719	618,206

TABLE 1.—(*Continued*)

Line Number	Total Oil Production, Bbl.		Total Gas Production, Millions Cu. Ft.				Number of Oil and/or Gas Wells							
								During 1937		At End of 1937				
	During 1937	Daily Average during Nov., 1937	To End of 1937	During 1936	During 1937	Maximum Daily during 1937	Completed to End of 1937	Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Oil and Gas[b]	Producing Gas Only	Total Producing
66	68,438	100									1			
67	33,172	63									1			
68	134,569	460									4			
69	4,968,169	11,811									118			
70														
71	268,422	626					69				69			
72														
73	774,825	1,844									70			
74	3,743,220	8,781									37			
75	2,087,016	4,962									237			
76											2			
77	45,628,117	105,121												
78	7,252,819													
79	311,264	659												
80	608,689													
81	580,948													
82	3,181,303	557									219			
83	1,014,189	2,532									107			
84														
85														
86							77				77			77
87														
88	425,889	769					36		1	1	34			34
89														
90														
91				0										
92	7,434,909	18,928									613			
93	331,265	852									36			
94	346,109	791									7			
95	242,258	534									8			
96	759,822	1,943									72			
97	847,005	1,876									18			
98	4,293,837										320			
99	1,205,850	2,960					27				27			27
100	471,227	1,394									22			
101				0										
102	103,528	144					6	0	2		4			4
103		[y]		0										
104		[y]												
105		[y]												
106		[y]												
107		[y]												
108		[y]												
109		[y]												
110		[y]												
111		[y]												
112		[y]												
113		[y]		0										
114	165,000	490					8	4			8			8
115		[y]												
116														
117	350,926	2,297									19			
118	715,360	1,647									44			
119	909,196	1,746									33			
120	93,552	[y]									1			
121	12,862	26									1			
122	26,316	222									1			
123	214,181	[y]									10			
124	26,051	100									1			
125	23,863	[y]									2			
126	297,172	1,247									18			
127	381,823	1,361									24			
128		965									18			
129	587,629	1,375									98			

TABLE 1.—(*Continued*)

Line Number	Depth, Average in Feet		Oil Production Methods at End of 1937			Pressure, Lb. per Sq. In.[d]			Character of Oil, Approx. Average during 1937				
			Number of Wells				Average at End of		Gravity A.P.I. at 60° F.				
	Bottoms of Productive Wells	To Top of Productive Zone	Flowing	Pumping	Misc.	Initial	1936	1937	Maximum	Minimum	Weighted Average	Sulphur, Per Cent	Base[e]
66						y	y		y	y	y	y	y
67						y	y		y	y	y	y	y
68						e2,200	2,200		y	y	y	y	y
69						y	y				42	y	y
70						1,950	y				40	y	y
71	4,140	4,130		69		e1,000y	50y				39	0.35	M
72						y	0		y	y	32	y	y
73						y	y				39	y	y
74											47		
75						y	y		39	37	39	y	y
76						y	y				39	y	P
77						e2,600	y				39	y	
78						e2,660	y				39	y	
79						y	y				40	y	
80						y	y						
81						1,000							
82						y	y		y	y	34	y	y
83						y	y		y	y	34	y	y
84													
85						y	y				39	y	y
86				77							37	0.1	M
87											36		
88	4,900	4,823		34	1	y	y		44	40			P
89						y	y				38	y	y
90						y	y				43	y	y
91						600	y		33	25	28		M
92						y	y				39	y	y
93						y	y				37	y	y
94						y	y				37	y	y
95						y	y				37	y	y
96						y	y				38	y	y
97						y	y				32	y	y
98						y	y				39	y	
99	4,115	4,085				e500	e50				40		M
100											34		
101						760	0		35	27	32	0	M
102	4,306	4,300		4		e1,700	e950		40	40	40		M
103						500	0		31	21	28	0	M
104						y	y				41		
105						y	y				40		
106						y	y				40		
107						y	y				42		
108						y	y				26		
109						y	y				40		
110						y	y			y	y		
111						y	y				41		
112						y y	y y		y	y	y 38		
113						300	0		21	17	26	0	M
114	4,290	4,240		8		e1,977	y		40	39	39.7	0	M
115						y	y				y		
116						1,665	x		y	y	y	y	y
117													
118													
119													
120													
121													
122													
123													
124													
125													
126													
127													
128													
129													

TABLE 1.—(*Continued*)

Line Number	Producing Rock						Number of Dry and/or Near-dry Holes to End of 1936	Deepest Zone Tested to End of 1937	
	Name	Age[f]	Character[g]	Porosity[h]	Net Thickness, Average in Feet	Structure[i]		Name	Depth of Hole, Ft.
66	Misener	Mis	S	Por	*y*	*y*			
67	Viola	Ord	L	Por	*y*	*y*			
68	Wilcox	Ord	L-S	Por	*y*	*y*			
69	Wilcox	Ord	L-S	Por	*y*	*y*			
70	Various	Pen, Ord	S	Por	*y*	*y*			
71	Misener-Hunton	Mis-Sil	S-L	Por	10	A	33	Wilcox	4,330
72	Wilcox	Ord	S	Por	6	*y*			
73	*y*	*y*	*y*	*y*	*y*	*y*			
74	2nd Wilcox	Ord	S	Por		A			
75	Burbank	Pen	S	*x*	*y*	*y*			
76	Trospex	Pen	S	Por	12	ML			
77	Wilcox	Ord	S	22.5	*y*	*y*			
78	Lower Simpson	Ord	S	Por	*y*	*y*			
79	Cleveland	Pen	S	Por	*y*	*y*			
80	Arbuckle	Cam, Ord	L	Cav	*y*	*y*			
81	Misener	Pen	S	Por	*y*	*y*			
82	Senora-Colvin	Pen	S	Per	*y*	*y*			
83	Senora-Colvin	Pen	S	Por	*y*	*y*			
84	Layton	Pen	S	Por	*x*	*y*			
85	Stalnaker-Oswego	Pen	SL	*y*	*y*	*y*			
86	Cromwell	Pen	S	Por	10	A		Wilcox	
87	Various	Pen-Ord	LS	Por	*y*	*y*			
88	Simpson dol., sand	Ord	SD	Por	45	A	5	Second Wilcox	
89	Various	Pen-Mis-Ord	S	*y*	*y*	*y*			
90	Wilcox	Ord	S	Por	*y*	*y*			
91	Pontotoc-Simpson	Per-Ord	SL	*y*	*y*	A, AV			
92	Hunton-Simpson	Sil-Ord	LS	Por	*y*	*y*			
93	Cromwell-Wilcox	Pen-Ord	S	Por	*y*	*y*			
94	Wilcox	Ord	S	Por	*y*	*y*			
95	Wilcox	Ord	S	Por	*y*	*y*			
96	Hunton-Wilcox	Sil-Ord	SL	Por	*y*	*y*			
97	Wilcox	Ord	S	*y*	*y*	*y*			
98	Wilcox (Simpson)	Ord	S	Por	*y*	*y*			
99	Wilcox	Ord	S	P	30	A		Wilcox	4,150
100	Earlsbora	Pen	S	Por	*y*	*y*			
101	Deese	Pen	S	30	40	A			
102	Wilcox	Ord	S	Por	6	A		Wilcox	4,306
103	Deese-Dornick Hills	Pen	S	30	60	AM, DL			
104	Various	Pen, Mis, Ord	SL	Por	*y*	*x*			
105	Not Determined	?	L	Por	*y*	*x*			
106	*y*	*y*	*y*	*y*	*y*	*y*			
107	Various	Pen-Ord	S	Por	*y*	*x*			
108	Deese	Pen	S	Por	*y*	A			
109	Stalnaker	Mis	S	Por	*y*	*x*			
110	Simpson	Ord	S	Por	*y*	*x*			
111	Wilcox-Layton	Ord-Pen	S	Por	*y*	*y*			
112	*y* Cromwell-Hunton-Wilcox	*y* Pen, Sil, Ord	*y* SL	*y* Por	*y* *y*	*y* *y*			
113	Pontotoc	Upper Pen	S	*y*		A			
114	Hunton	Sil	L	*x*	50	A		Wilcox	4,520
115	Hunton	Sil	L	*y*	20	*y*			
116	Wilcox	Ord	S	Por	34	A			
117									
118									
119									
120									
121	Wilcox								
122	Wilcox								
123	Wilcox								
124	Dolomite								
125			S						
126			S						
127	Wilcox		S						
128	Hunton								
129	Cromwell								

TABLE 2.—*New Oil Areas Discovered in Oklahoma in 1937*

Name of Pool	County	Name of We	Location of Discovery Well			Company	Date Completed	Initial Production per Day, Bbl.	Total Number of Wells	Estimated Daily Capacity, Bbl.	Producing Formation	Average Depth, Ft.	Accumulated Runs to Dec. 1, 1937, Bbl.
			Sec.	Twp.	Rge.								
Airport	Tulsa	Fee No. 1	35	20 N	13	Gubser	1-30-37		53	149	Bartlesville	1,000	87,358
North Bethel[1]	Seminole	Yahola No. 1	36	10 N	7 E	Amerada	10-28-36	1,400	30	25,020	Cromwell	3,647	902,062
Citra	Hughes	Hamilton No. 1	33	4 N	9 E	Carter	7- 9-37	192	1	23	McLish	6,177	4,278
South Cromwell	Seminole	Rosana No. 1	28	10 N	8 E	Sinclair Prairie	4- 6-37	380	4	310	Simpson	4,189	52,897
Dora[1]	Seminole	Flowers No. 1	29	7 N	6 E	Malernee-Shell	12- 3-36	150	17	2,091	Sonora sand	2,950	277,852
Doyle, deep sand	Stephens	Graham No. 1	12	1 N	5 W	Helmerich-Payne	6- -37	68	4	259	Hoxbar	3,870	37,489[3]
Fitts, Cromwell	Pontotoc	Woodroof No. 5-A	29	2 N	7 E	E. H. Moore	2- 1-37	108	107	12,000	Cromwell	2,615	650,656
South Fitts	Pontotoc	Muse No. 1	33	2 N	7 E	E. H. Moore	4- 6-37	102	11	243	Hunton	5,200	53,626
South Fitts, Gilcrease	Pontotoc	Scott-Brown No. 1	34	2 N	7 E	E. H. Moore	7-28-37	100	2	100	Gilcrease	1,875	11,588
West Fitts	Pontotoc	Booth No. 1	20	2 N	6 E	Simpson-Roodhouse	6-28-37	68	6	300	Cromwell	3,100	10,402
Frederick	Tillman	Graham No. 1	1	3 S	9 W	I. T. I. O. Co.	8-27-37	500	2	800	Canyon lime	4,400	41,689
Frederick, Hatler area	Tillman	Hatler No. 1	32	2 S	17 W	I. T. I. O. Co.	1-24-37	130	1	50	Canyon lime	4,529	12,480
Jesse Hunton, new area	Pontotoc	Thompson No. 1	2	1 N	7 E	Continental	6-17-37	3,528	16	7,500	Hunton	4,160	92,904
Lamont	Grant	Crisman G-55 No. 1	16	25 N	3 W	Carter	9-24-37	242	1	242	Wilcox	5,410	54,873
Langston, new area	Logan	Smith No. 1	13	17 N	1 W	Eason	5- 1-37	2,784	7	5,800	Wilcox	5,128	141,566
North Lucien[1]	Noble	W. H. Moelling No. 1	31	21 N	2 W	Shell	12-15-36	4,848	4	2,904	Bromide	5,389	130,632
Okla. City, Pawhuska	Oklahoma	Fortson No. 1	24	11 N	3 W	I. T. I. O. Co.	7-24-37	500	5	5,000	Pawhuska	3,000	110,326
Okla. City, Tonkawa	Oklahoma	Theimer No. 2	12	11 N	3 W	I. T. I. O. Co.	5- 8-37	2,500	10	1,100	Tonkawa	4,450	199,663
Okla. City, Upper Simpson Dol.[1]	Oklahoma	Wheeler No. 1	15	12 N	3 W	Ander.-Prichard	7- 1-36	72	17	1,773	Upper-Simpson Dolomite	6,450	788,579
Shawnee, East	Pottawatomie	Logan No. 1-A	31	11 N	5 E	Mid-Continent	5- 8-37	250	1	30	Wilcox	4,843	11,689
Shawnee, North	Pottawatomie	NeThahPeaSe No. 1	24	11 N	4 E	Mid-Continent	8-13-37	210	1	210	Wilcox	4,886	20,075
Sporn	Lincoln	Williams East No. 2	21	17 N	3 E	Skelly	1- -37	292		720	Wilcox	4,600	194,062
Tecumseh	tawatomie	Billington (B) No. 1	32	9 N	3 E	Stanolind	6-30-37	5,612	1	5,612	Dolomite	5,238	22,908
Traugh[1]	Seminole	Williams No. 1	22	6 N	6 E	R. P. Traugh	12-15-36	126	18	1,200	Sand (Sonora?)	2,360	264,328
Traugh, deep sand	Seminole	Amason No. 1	15	6 N	6 E	W. B. Pine	8-25-37	8,136	2	10,000	Sand	3,779	20,766
South Weleetka	Okfuskee	Sands-Deere No. 1	28	10 N	11 E	A. S. Berry	3-19-37	100	2	84	2nd Gilcrease	2,700	12,834
North Wellston	Lincoln	Eakers No. 1	35	15 N	2 E	Stanolind	1-13-37	676	26	23,459	Wilcox	5,140	340,286
South Wilzetta[1]	Lincoln	Simmerman No. 1	10	12 N	5 E	Amerada	6-27-36	272	4	292	Hunton	4,400	517,539
Milroy, deep	Stephens	Harley-C-49 No. 1	24	2 S	4 W	Carter	8-25-37	2,640		2,640	Oolitic	8,157	78,000
Ramsey	Payne	Ramsey No. 1	18	18 N	2 E	Mid-Continent	12-28-37[2]		1		Wilcox	4,771	
								35,986	354	109,911			5,143,407

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[1] Discovered in 1936 but developed in 1937.
[2] Production test not made until Jan. 3, 1938.
[3] Estimated.

deep well was drilled into a new zone, which has been classified by some as being in the Hoxbar series.

Edmond Pool.—Several wells were completed in the Edmond pool during the year. This field appeared to be rather well defined at the end of 1937.

Billings Pool.—Several wells were completed in the deep Wilcox horizons in Billings pool for substantial production.

Tulsa Area.—During the year town-lot activity took place in Tulsa's back yard; 53 wells produced approximately 87,000 bbl. of oil during the year. This pool was designated as the Airport pool, being close to Tulsa's municipal airport.

Water-flooding.—Water-flooding as a means of secondary recovery in the old oil fields continued to increase in 1937. Several of the operators in the old Nowata pool in Nowata and Rogers County expanded their operations. During the year, 427 water-intake wells were drilled in eastern Oklahoma. Many of the technical problems are being solved and it appears that 1938 will see a continuation of secondary recovery projects and some probable additions. New methods are being developed with accompanying lower costs.

Gas Repressuring.—Many gas repressuring projects are being carried out in northeastern Oklahoma; 132 wells were drilled for that purpose in that part of the state during 1937. A number of pressure wells were drilled on the unitized block of approximately 5000 acres in central eastern Osage County. This is a unitized project which the Sinclair-Prairie Oil Co., Phillips and the Wolverine Petroleum Co. have undertaken.

South Burbank Unit Block.—The unitization of the South Burbank field continued during the year 1937. This block comprises more than 2400 acres and included most of the producing acreage on the structure. By the introduction into the producing horizons of the gas that accompanies the oil, bottom-hole pressures have been maintained without any substantial decline for the past several years.

General.—The disposal of salt water and other oil-field wastes continues to be one of the oil industry's problems. The Oklahoma Planning and Resources Board continued to cooperate with the oil industry in the disposal of salt water in several of the fields, the oil operators and the Board carrying out a cooperative program of salt-water disposal for the Fitts pool.

ACKNOWLEDGMENTS

The author desires to acknowledge the assistance of Mr. W. J. Armstrong, of the Corporation Commission of the State of Oklahoma, and the records and data made available through his courtesy; also, the assistance of Mr. H. B. Davidson, of the Corporation Commission of the State of Oklahoma, with reference to the information contained in

Table 2, most of this information having been accumulated by Mr. Davidson, and also his assistance in preparing Table 1. The author also desires to acknowledge gratefully the assistance of Mr. C. H. Pishney, Amerada Petroleum Corporation, who assisted materially in the compilation of data contained in Table 1; and data contributed by Messrs. L. F. McCollum and Thomas Brownfield, Carter Oil Co.; Mr. Merritt H. Brown, Darby Petroleum Corporation; Mr. George Beaulieu, Osage Indian Agency; and Miss Lena Allen.

Oil and Gas Development in Northern and Central Pennsylvania during 1937

By Arthur C. Simmons,* Member A.I.M.E.

In common with all other producing areas of the United States, Pennsylvania enjoyed increased activity and prosperity during 1937 (Table 1). Prices of crude oil were better than for any year since 1930, and the Bradford average was $2.599, compared with an average price of $2.60 in 1930. Production and drilling activities were increased over 1936, although drilling for oil represented almost entirely a program of secondary development in both the water-flood areas and the air-gas repressuring areas.

Bradford Oil Field

The Bradford oil field continued to produce the major portion of Pennsylvania oil; however, no changes occurred in oil-production methods during 1937. Practically all of the production in the Bradford field is by water-flooding and the total number of oil and water wells completed within the area increased from 3205 in 1936 to 4112 in 1937; an increase of approximately one-third over 1936 completions. The percentage of water wells is approximately one-half of the total completions, although any specific five-spot development will have a proportion of 55 to 60 per cent water wells and 40 to 45 per cent oil wells. Offsetting and boundary oil wells probably will result in a division or percentage of 50 per cent oil and 50 per cent water wells. The quoted figures for well completions include the entire Bradford field, approximately 12 per cent of which is in Cattaraugus County, New York. It is possible to make a segregation of production, but it is not possible to segregate well completions.

Production in the Pennsylvania end of the Bradford field in 1937 totaled 15,076,000 bbl., or a daily average of 41,300 bbl. compared with a daily average of 37,000 bbl. in 1936.

Table 1.—*Oil Production in Pennsylvania in* 1937

	Bradford[a]	Kane-Butler	S. W. Pa.	Total
Total, bbl.	15,076,909	3,140,550	967,550	19,185,009
Daily average, bbl.	41,300	8,604	2,651	52,562

[a] Includes only production in Pennsylvania.

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Prices for crude oil varied from a minimum of $2.20 to a maximum of $2.82, with a yearly average of $2.599.

No outstanding new developments occurred in water-flooding practices, although a gradual trend can be observed toward higher water-input pressures and a greater interest and emphasis are now being placed on the quantity and quality of the flood water.

MID-PENNSYLVANIA AREA

The areas discussed in this section fall into two natural geographic and geologic groups: (1) The Clarendon field, in Mead and Sheffield townships, Warren County, Pa., and (2) the producing area extending from Grand Valley, Warren County, through Crawford, Venango, Forest and Clarion Counties to the Butler County line. These areas contain a series of individual and connected pools, which have local names but are not of sufficient size or consequent importance to deserve special mention.

The Clarendon field produces a light amber, 45° gravity oil, which has been known on the market as Tiona crude. The main producing horizon is the Clarendon sand, which lies at a depth of approximately 1000 ft. below stream level and geologically occurs in the Chemung formation of upper Devonian age. It is a fairly hard, white sandstone, capped by a coarse, well cemented conglomeratic sandstone, known as the "cap." The lower part of the sand body grades off into shaly sand and interbedded shale lenses, so that there is no definite bottom or lower limit. Cores have shown that the upper part, which is softer and not as well cemented as the lower part, has been the principal pay zone. Saturation in this upper zone is from 250 to 450 bbl. per acre-foot with a permeability ranging from 10 to 100 millidarcys. The thickness of this zone varies in different parts of the field from nothing where the sand is thin to a maximum of 16 ft. The lower zone contains from 100 to 250 bbl. per acre-foot and has a permeability of less than one millidarcy.

During the last few years, several attempts have been made to successfully flood this sand. None of these have progressed sufficiently to give results that would generally apply to the entire field. One five-spot flood started in 1930 has been physically successful and the percentage recovery has been slightly less than a Bradford field average. Active operations, commenced in 1935 and 1936, have extended flooding in the original and other new areas. There are at present approximately 200 acres under five-spot flood development.

The five-spot pattern has been used with well spacings of 330 to 400 ft. (water to water). Pump pressures vary from 850 to 1200 lb. per sq. in., and the average intake quantity is from 6 to 40 bbl. per day, depending on the usual factors of sand capacity and pressure. Oil wells exhibit the usual characteristics of flood wells.

In 1937 approximately 40 water wells were drilled and an equal number of oil wells in the Clarendon field. About 95 wells were drilled in the rest of the field, to be pumped as natural oil wells.

Statistics on crude runs from this field are not available, so that the effects of these developments cannot as yet be interpreted. It is estimated, however, that there has occurred an increase in production of approximately 100 bbl. per day.

Titusville-Oil City District

The area beginning at Grand Valley, Warren County, and extending southward through parts of Crawford, Forest, Clarion and Venango Counties to the Butler County line, contains many small oil pools, some of which have local names, but few, if any, can be conveniently designated as separate or individual pools.

The producing horizons in this area are the Venango First, Second, Third and Fourth sands, with occasional stray sands locally productive and named. It is believed that in many places these stray sands will correlate with the major horizons with additional correlation and study.

The total productive area of this region includes approximately 188,000 acres, of which 130,000 acres are in the Titusville-Oil City district, and the remainder is in scattered, isolated oil-gas pools in Clarion and Elk Counties. It is difficult to give a picture of the extent of production by actual surface areas, because in many places the sands overlap and some properties produce oil from as many as four horizons.

The First sand is productive in distinct pools, which have an indefinite relationship with each other. The sand is generally coarse to fine white, fairly well cemented sandstone. The Second sand is probably the most uniform and widespread formation; however, the pools are widely scattered. The productive area of the Third sand is greater than either the First or Second, and varies considerably, even on a single property, ranging from a hard, fine sandstone to a coarse, uncemented conglomerate.

Considerable coring has been done in the last few years, but the results cannot as yet be interpreted with definite conclusions. Several cores are necessary on each lease or property before any safe deductions can be made.

The oil content of the Venango sands is more uniform than the permeability, but the present oil content varies widely both laterally and vertically throughout these areas. The permeability varies over a wide range extending from less than one millidarcy in a hard, well cemented sand to over 2000 millidarcys in an open conglomerate.

Intensive developments of secondary recovery were started in 1935 and 1936, and continued through the early part of 1937. Drilling and development activities decreased after the first price decline in August, until at the end of the year only a few rigs were in operation.

The *Oil City Derrick* reports the completion of 379 wells in the mid-Pennsylvania area, of which 11 were dry, 18 were gas wells, 105 were pressure intakes and 245 producing oil wells. This is approximately the same amount of drilling that took place in 1936. Production from the mid-Pennsylvania increased in 1937, as shown by Fig. 1. The figures indicate an increase of approximately 600 bbl. per day, and since they represent the whole mid-Pennsylvania area, including the water-flood production of the Clarendon field, the net increase of the lower district is indicated at 500 bbl. per day.

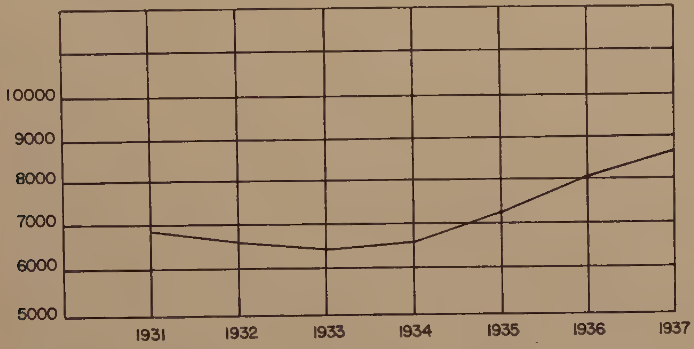

Fig. 1.—Average daily production in mid-Pennsylvania.

Only one deep test was attempted in the lower district, and this one. in Rockland township, is temporarily shut down before reaching its objective, the Oriskany sand.

New Developments

An outstanding new discovery occurred in September of 1937, when the discovery well of Niagara Oil Corporation opened a new pool 9 miles south of Bradford. The producing horizon is Devonian sand variously correlated, named Second, Cherry Grove, Watsonville, or Sliverville. This sand is approximately 300 ft. above the Third or Bradford sand of the Bradford field, and the discovery well started with an initial production variously estimated at 4000 to 6000 bbl. per day. This discovery is an isolated pool, for old wells drilled in the Bradford and Kane sands are near by. The productivity, yield and defined area are as yet indefinite, although at the close of the year several additional flowing wells and dry holes had been completed in the immediate vicinity of the first well. Such a new oil discovery is very unusual in the old fields of Pennsylvania and the economic importance of this discovery is as yet undetermined.

No new Oriskany gas fields were developed during 1937 but additional drilling occurred in Hebron, Sabinsville, Harrison, and the near-by fields in New York State.

New developments in Pennsylvania during 1937 consisted in the main of the discovery of the Sliverville pool on Music Mountain, 9 miles south of Bradford, and the drilling with rotary equipment of a deep well (8000 ft.) in Keating township, Potter County. At the close of 1937 there were drilling, or contracted for, three deep rotary wells, using heavy Mid-Continent rigs, to test the deeper horizons for oil or gas production.

Acknowledgments

Acknowledgment is made to Mr. Norman E. Maxwell, of the Crew-Levick Co., Titusville, Pa., for the data and description of the mid-Pennsylvania area.

Oil and Gas Developments in Southern Pennsylvania during 1937

By John T. Galey,[*] Junior Member A.I.M.E.

Oil and gas development in southern Pennsylvania during 1937 was marked by considerably increased activity in deep-sand drilling. Nine tests were completed to the Oriskany sand: one in Independence and three in South Beaver townships, Beaver County; one in Franklin township, Butler County, two in Slippery Rock township, Lawrence County; one in Mt. Pleasant township, Washington County, which is drilling below the Oriskany, and one in Fairfield township, Westmoreland County. Two of these wells, both of which were in the Blackhawk pool, South Beaver township, Beaver County, obtained wet gas with open-flow volumes of 1.5 million cu. ft. and 3.1 million cu. ft. and closed-in pressures of 1900 lb. The remaining seven were unproductive in the Oriskany. Two wells, one in Hampton township, Allegheny County, which is shut down temporarily as a result of a gas pocket, and one in South Beaver township, Beaver County, are drilling to the Oriskany.

One deep test on the Chestnut Ridge anticline, South Union township, Fayette County, was completed after considerable difficulty as a dry gas well in the Onondaga limestone. At this locality the cherty limestone is porous as a result of fracturing. Three additional tests are under way in the area, one in South Union township, a second in North Union township, and a third in Wharton township.

Completions

Oil.—Despite price cuts and production curtailment of Pennsylvania Grade crude, caused largely by a decreasing demand from export markets, operation in the shallow oil areas continued at a fairly high rate and a number of good wells were completed. Some of these were new wells in close proximity to old production and others were old wells drilled into deeper pays. One new well of a number of producers drilled to the Nineveh Thirty-foot sand in the Harvey pool, Center township, Green County, made 400 bbl. of oil and 500 million cu ft. of gas the first 24 hr. The Chambers dam pool of Amwell and South Franklin townships, Washington County, yielded a number of Fifth Sand producers with initials as high as 200 bbl. Several wells in the old Mars-Butler field

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near Valencia, Adams township, Butler County, were successful completions in the Hundred-Foot sand with initial production of 25 bbl. of oil accompanied by considerable salt water. In Ross township, Allegheny County, a well flowing 350 bbl. with considerable gas, from the Hundred-Foot sand was brought in and caused a small town-lot excitement. Subsequent results in finding a pool were disappointing, as only one 50-bbl. well gave more than a show from that sand. However, in deepening some of the dry holes to the Fifth sand, worth-while gas production has been obtained. One well completed recently had an initial open flow of 1.5 million cu. ft. with a closed-in pressure of 625 lb. In Washington township, Greene County, a well formerly productive in the Gas sand was drilled to the Fifty-foot sand, with 100 bbl. initial production.

Gas.—Few of the gas wells drilled gave promise of large reserves. However, in the vicinity of Upper Middletown, Menallen township, Fayette County, one gas well was brought in making 5 million cu. ft. from the Big Injun sand, which caught fire and after being brought under control was found to have a closed-in pressure of 600 lb. This seems remarkable, inasmuch as considerable gas has been taken from this area since development commenced in 1920. Lately, drilling has been carried on at a rapid rate and wells having initial open flows of from 1.5 to 3 million cu. ft. are being found principally along the east flank of the plunge of the Fayette anticline from Upper Middletown southwest through German, Nicholson and Spring Hill townships. A 5-million-cu.-ft. well was completed to the Salt sand in North Strabane township, Washington County, but apparently efforts to extend this find into a pool have failed.

EQUIPMENT AND OPERATION

The heaviest string of casing handled to date in a dry hole in the east was successfully landed in the Tully limestone at 6190 ft. in the deep test in Mt. Pleasant township, Washington County. This string consisted originally of 300 ft. of 38-lb. and 5890 ft. of 36-lb. 8⅝-in. Extreme-Line casing and was subsequently extended to 6485 ft. by underreaming and setting in the Onondaga limestone. Another long string consisting of 7600 ft. of 6⅝-in. 26.4-lb. casing was successfully landed in the deep test in Fairfield township, Westmoreland County. This was also run in a dry hole.

Cable tools are still employed exclusively in all deep-drilling operations, and explosive gas pockets with accompanying caves and resultant fishing jobs present the main obstacle to be overcome in keeping drilling costs within reasonable bounds. One experiment has been conducted in a well in the Blackhawk pool, South Beaver township, Beaver County, for the purpose of determining the feasibity of controlling the explosive gas pockets while they are being drilled with cable tools. It had been observed that salt water of the character of an Oriskany brine minimized the tendency to cave of the shale series in which the gas pockets occur. Consequently, a column of approximately 2000 ft. of Oriskany brine was put into the hole at a point 100 ft. above the Tully lime below which the gas pockets are expected. No difficulty was experienced in running a stem of small diameter and bit of enlarged water course on a swivel socket with this column of fluid in the hole until almost 200 ft. had been drilled and a number of gas pockets encountered. At this point it was found that the column of fluid had become so muddy, even though approximately 50 bbl. of brine had been exchanged, that the tools would not drill ahead. The fluid was then bailed from the hole, neat cement poured in and drilled out after setting for 3 hr. This process was repeated but once before the Onondaga limestone was encountered. Thus this dangerous part of the hole was drilled as an almost routine matter.

Tubing under pressure and bottom-hole choking have been employed in the Blackhawk pool, resulting in minimizing the danger of running tubing, conserving gas and permitting back pressures to be held, which are necessary in order to prevent freezing in the sand without the use of surface chokes. A plan of unit operation has been effected in this pool, which should work to the advantage of both the operator and the landowner.

Geophysical Work

Seismograph surveys have been conducted in Beaver, Butler, Fayette, and Lawrence Counties during 1937, and it appears that the Tully limestone is the most suitable reflecting horizon for working subsurface structure, as the Tully has been recognized from drill cuttings in the deep wells of this area and the rate of divergence between the Tully and Oriskany determined with sufficient accuracy to enable the geologist to depict the high of the Oriskany structure. A deep horizon, possibly the Trenton limestone, approximately 4500 ft. below the Onondaga in Beaver County, seems to yield workable reflections.

Legislation

A particularly timely piece of legislation has been passed recently by the General Assembly of the State as Act. No. 570, which requires the filing of records together with locations of wells and reasonable samples of drill cuttings and provides penalties for failure so to do.

Outlook for 1938

While considerable knowledge concerning not only the deeper but also the shallower heretofore mapped structures has been gained from seismograph, subsurface, and surface studies, the task of correlating several important key beds has not yet been accomplished, and an accurate picture of the deeper structures, particularly those toward the Allegheny front, has not yet been obtained, more concentrated and intelligent study will be given these problems than ever before. The reason for this is obvious. New gas pools are not being discovered rapidly enough to make up for the depletion of the old ones, and oil production in the Oriskany or deeper horizons in the vicinity of the bottom of the Oriskany Basin seems to be within the realm of possibility. Improvement in drilling technique, possibly the introduction of the rotary, will permit the testing of whatever traps are found. Beyond much question, the greatest attempt at development of deeper horizons yet undertaken in this area should be made in 1938.

Oil and Gas Developments in Tennessee in 1937

By Kendall E. Born,* Junior Member A.I.M.E.

Production of crude oil in Tennessee during 1937 was slightly over 37,000 bbl., an 85 per cent increase over the preceding year and the highest since 1928. Closer cooperation between the operators and the State Division of Geology has resulted in more accurate data than have been possible for the past few years. Such cooperation is most desirable, especially in this state, which has no law requiring the filling of drilling permits, logs, and production figures.

The increased production for the year has resulted from discoveries of four small pools in the shallow district of Clay and near-by counties. The most promising of these began production late in 1937 and consequently has had little effect on the 1937 total. These discoveries, along with renewed activities in some of the older areas, have increased the production for Clay and adjoining counties from less than 5000 bbl. during 1936 to over 21,000 bbl. in 1937.

The Mississippi lime production in Scott and Morgan Counties declined from 16,335 bbl. in 1936 to 14,644 bbl. during 1937. While the decline curve on this production has been gradual, some of the wells are over 20 years old, and it becomes necessary to look for other favorable structures in this general region if increased production is to be obtained or past production maintained.

The only natural gas marketed off the lease in Tennessee during 1937 was in Morgan County, where a small amount was furnished for the town of Sunbright and its immediate vicinity. The gas occurs with the oil in the Boone Camp field and small amounts were put on the line from the near-by Coon Hollow and Seabolt pools.

Development

There were 59 wells spudded in during 1937, of which 18 were drilling or only temporarily shut down on Dec. 31, 1937. Of the 41 completions, 17 produced oil, 5 were gas wells of undetermined quantity, and 19 were dry or near-dry holes. The flush production on the new wells totaled about 1300 bbl. per day. The more important wildcats are listed in

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Table 2 and the distribution of oil and gas tests drilled during the year, according to physiographic divisions, is given in Table 3.

Cumberland Plateau

There was only one completion in 1937 in the coal region of the state. The Russell Producing Company's Markley 1, drilled on the south edge of the Coon Hollow pool, was completed in February as a 2-bbl. producer from the "Glenmary" pay of the upper Mississippian. After acidizing with 1000 gal. in April, the well pumped 11 bbl. of oil per day and gauged 30,000 cu. ft. of gas.

An adverse opinion was handed down late in 1937 by the Railroad and Public Utilities Commission on a petition to distribute natural gas in Knoxville from the Sunbright field, Morgan County. However, interest persists in the gas possibilities of this general area and one well is drilling in the central part of Morgan County.

Northeastern Highland Rim

The principal oil and gas interest in Tennessee during 1937 centered in Clay, Jackson, Overton, Pickett and Fentress Counties on the northeastern Highland Rim. There were 35 completions, 16 of which produced oil and 5 gas. Three of the oil wells, which were less than 5 bbl., were almost immediately abandoned. There were 15 rigs running in the general area on Dec. 31, 1937.

Clay County.—The most important developments in Clay County in 1937 were the discoveries of three pools, two of which began production late in the year. Interest in the shallow possibilities in Clay County were revived early in the year by the drilling in of a flowing well along the Tennessee-Kentucky line just north of Lillydale. The well was an old one deepened from 711 to 726 ft. During the year the well was drilled still deeper and another pay was penetrated. In an effort to extend this production, three tests were completed in the immediate vicinity; two were dry holes and one furnished a considerable quantity of gas.

Early in 1937 a test well on the John Hargrove lease, one mile southwest of Willow Grove in central Clay County, came in flowing about 125 bbl. per day at a depth of 671 ft., 195 ft. below the Pencil Cave. The location was on a well defined upwarp mapped by the State Division of Geology in 1923. For about two months, approximately 100 bbl. per day was pumped; the production declined rapidly, the well was drilled deeper and a 3-bbl. pay was struck at 750 ft. During the year five other wells were drilled on this lease, three of which produced oil from the Stones River limestones and one produced a small amount from the lower "Sunnybrook" pay just above the Pencil Cave. The Hargrove pool produced 10,250 bbl. during the year. The No. 7 well was drilling on Dec. 31, 1937.

In August a test well on the Cordell Hull lease, 4 miles north of Celina along Pine Branch, penetrated an oil pay at 481 ft., 55 ft. below the Pencil Cave, and pumped 50 bbl. per day for two weeks. When deepened to 516 ft. the well flowed an initial of 600 bbl. per day, but the production soon leveled off at 120 bbl. Two offset wells had a combined production of about 100 bbl. per day. These three wells, known as the Pine Branch pool, produced 6993 bbl. during the last four months of 1937. In January 1938, a 200-bbl. well was completed in the same pool.

A 50-bbl. producer in Goodpasture Bend of Obey River, 5 miles east of Celina, has opened the possibilities of the general area northeast of the old Peterman Bend production. This well, completed late in November, reported the pay at 465 ft. 117 ft. below the Pencil Cave. The No. 2 well is now drilling. Some half-dozen scattered wells in Clay County failed to find production, although all but one were drilled into the pay horizons below the Pencil Cave.

TABLE 1.—*Oil Production in Tennessee for* 1937

Line No.	Field, *County*	Age, Years to End of 1937	Production in 1936, Bbl.	Production in 1937, Bbl.	Number of Wells Pumped in 1937	Producing Rock				Structure[i]
						Name	Age[f]	Character[g]	Porosity[h]	
1	Glenmary, *Scott*	21	5,012	4,629	4	Glenmary	MisU	L	Fis	AF
2	Boone Camp, *Morgan*	15	1,541	1,860	12	Boone Camp	MisL	LS	Fis	T
3	Seabolt, *Morgan*	9	2,250	2,175	4	Boone Camp	MisL	LS	Fis	T
4	Coon Hollow, *Morgan*	8	7,532	5,980	5	Glenmary	MisL	L	Fis	T
5	Poplar Cove, *Fentress*	7	5*xx*	1*xx*	2	Sunnybrook	Ord	L	Fis	N
6	Beaty, *Fentress*	6 mo.		1,*xxx*	1	Sunnybrook	Ord	L	Fis	D
7	Tinsleys Bottom, *Clay-Jackson*	13	5*xx*	2,005	8	Tinsleys Bottom	Ord	L	Fis	D
8	Jouett Creek, *Pickett*	10		530	1	Tinsleys Bottom	Ord	L	Fis	A
9	Pine Branch, *Clay*	4 mo.		6,993	3	Tinsleys Bottom	Ord	L	Fis	A
10	Hargrove, *Clay*	10 mo.		10,250	5	Tinsleys Bottom	Ord	L	Fis	D
11	Goodpasture Bend, *Clay*	2 mo.		5*xx*	1	Tinsleys Bottom	Ord	L	Fis	N
12	Scattered, *Clay*[1]		5*xx*	1,1*xx*	5	Tinsleys Bottom	Ord	L	Fis	

[f] Footnotes to column heads and explanation of symbols are given on page 313.

[1] Scattered production in Clay County includes the Clark lease north of Lillydale, on the Kentucky-Tennessee line, two wells in the Mill Creek district, and the Keisling lease just northeast of Peterman Bend.

Jackson County.—Efforts during the year to revive the production in Tinsleys Bottom along the Clay-Jackson County line were not encouraging. Several of the old wells, some of which are 10 years old, were put on pump with indifferent results. The few wells that were acidized responded poorly, although the condition of the holes before acidizing is not known. Water appears to be the most important problem. Six new wells were completed in the pool, but no consistent pays were found. Three of the wells made a small amount of oil. The largest was 60 bbl. per day, but the pay was pumped dry after 500 bbl. had been produced. The entire pool had a reported production of 2005 bbl. in 1937.

Late in the year there were plans to clean out and pump some of the old wells in the Lock Branch pool, about 6 miles north of Gainesboro along Cumberland River. Details of progress are not available at this writing.

The deepest test in Jackson County during the year was in the northeastern part. This well, supposedly located on structure, was drilled to 1443 ft. and abandoned in salt water. At 1200 to 1210 ft. a sandy limestone was logged, which may represent the so-called "St. Peter" horizon. The green lime, often present about 60 ft. above the "St. Peter," was penetrated at 1156 to 1163 feet.

TABLE 2.—*Important Wildcat Tests Drilled in Tennessee during* 1937

Well Name	Well No.	County	Location	Drilled by	Total Depth, Ft.	Surface Formation	Deepest Formation Tested	Remarks
C. H. Buford	1	Clay	Goodpasture Bend of Obey River, 5 miles east of Celina	B. Davis et al.	465	Leipers	Lebanon	Oil; 50 bbl. flush at 465 ft.
John Hargrove	1	Clay	One mile southwest of Willow Grove in Stillhouse Hollow	Crispin, Hedgcock and Cary	800	Leipers	Stones River	Oil; 125 bbl. flush at 671 ft.; 3 bbl. pay at 750 ft.
Cordell Hull	1	Clay	Four miles north of Celina on Pine Branch	Miller and Overstreet	516	Leipers	Lebanon	Oil; 50 bbl. per day at 481 ft.; 600 bbl. flush at 516 ft.
P. P. Beaty	2	Fentress	Gooseneck Bend of Obey River, about 9 miles southwest of Jamestown	S. P. Lalor et al.	640	Osage	Trenton	Oil; 100 bbl. flush at 640 ft. in lower "Sunnybrook"
Thomas Scantland	1	Jackson	Swan Hollow of Murphy Branch, about 8 miles north of Gainesboro	W. F. Carter et al.	1,443	Leipers	Upper Knox	Shows. Dry "St. Peter" test; shows in "Sunnybrook"
Lem Motlow	1	Moore	On Bennett Branch, 1½ miles southeast of Raus	Farnham Brothers	1,335	Osage	Upper Knox	Dry. Drilled through the "St. Peter"
Fletcher-Brown	2	Overton	Near head of Mitchell Creek, ½ mile south of Clay County line	Cox, Greenup, and Spivy	1,120	Leipers	Murfreesboro	Oil; small amount at 1020 ft.; now abandoned
Andrew Phillips	1	Pickett	One mile southeast of Vans Branch School, near Clay County line	Robinson Oil Co.	1,404	Osage	Upper Knox	Oil; 600 ft. oil in hole at 1384 to 1390 ft. in "St. Peter"
Slayton	1	Sumner	Three miles west of Turners Station, just south of Kentucky line	George Shwab et al.	1,015	Osage	Stones River	Shows. Dry lower Ordovician test; show in Silurian at 160 ft.
Shepard Heirs	1	Perry	Northern edge of Beardstown	H. L. White	Drlg.	Silurian		Tested Silurian possibilities; in lower-Ordovician at 850 ft.

Overton County.—Developments in Overton County were in areas immediately adjacent to Clay County. Two wells were drilled on the same lease on the upper part of Mitchell Creek. One found a heavy flow of gas, gauged at 1,840,000 cu. ft., at 772 ft. This pay is 355 ft. below the Pencil Cave horizon. The No. 2 well produced a small amount of oil from a horizon, probably in the Murfreesboro limestone (Stones River), at 1020 ft., 597 ft. below the Pencil Cave.

Two tests were drilled near the head of Mill Creek, a short distance east of the old Mill Creek production, in northwestern Overton County. In one test a good show at 600 ft. was shot and the well probably would have made 1 bbl. per day. The other was dry to 702 feet.

Pickett County.—The deepening of an old well in the abandoned pool of western Pickett County near the Clay County line resulted in a

100-bbl. per day flow at 595 ft. This pool produced a considerable amount of oil from the "Sunnybrook" horizon about 10 years ago. The successful deepening to the sub-Pencil Cave pays of Clay County has resulted in renewed activity in the Jouett Creek district.

The most significant well drilled in Tennessee during 1937 was in the northwestern part of Pickett County, where a test penetrated a pay, the so-called "St. Peter," at 1384 to 1390 ft., 1334 ft. below the base of the Chattanooga shale. There are reports that 600 ft. of fluid rose in the hole, but at the present writing this well has not been put on pump, presumably because of the inability of the lessee to round out his block of acreage. This well is being watched with interest, since it suggests the opportunity for deeper pays in the northeastern Highland Rim region.

Fentress County.—There were five completions in the Highland Rim area of Fentress County; one was an oil producer and three were gassers. The producing well is in Gooseneck Bend of Obey River, about 9 miles southwest of Jamestown and 2 miles east of the old Spurrier-Riverton production. This well, the second on the lease, came in flowing during the summer at a depth of 640 ft. in the lower "Sunnybrook" horizon of the Trenton. Some 2000 bbl. of oil were reported lost before the well could be controlled. However, in November it was pumping about 5 bbl. per day. The No. 1 was a gas well and No. 3 was dry in the same horizon, which is producing in the No. 2.

Middle Tennessee

In middle Tennessee there were only three completions and all were dry or near-dry holes. In Sumner County, on the northern Highland Rim, a well drilled on structure penetrated the Chattanooga shale at 100 to 135 ft., and after encountering a good show in the Louisville (Silurian) limestone at 160 ft. was drilled on to 1015 ft. without finding encouraging shows in the deeper horizons. This test logged the Pencil Cave at 880 to 885 ft. and tested some of the higher "Tinsleys Bottom" pays of Clay and adjoining counties.

Two tests were drilled in Moore County, in the southern part of the eastern Highland Rim, one of which reached a depth of 1335 ft. This test penetrated the Chattanooga shale at 98 to 110 ft. and the Pencil Cave at 445 to 446 ft. A 10-ft. sandy gray limestone at 1275 to 1285 probably represents the "St. Peter" horizon. The other test well was shallow and ended in the upper part of the Stones River group of limestones.

In the Central Basin a 765-ft. test north of Woodbury in Cannon County tested the Clay County pays without a show of oil or gas.

A well now temporarily suspended in Beardstown, Perry County, in the Western Valley region encountered about 300 ft. of Silurian beds and is now some 550 ft. in Ordovician rocks, probably of Stones River age. Only light shows of oil and gas have been reported.

West Tennessee

There were no completions in the Mississippi embayment region of Tennessee, although leasing has been active in certain areas. The Henderson Oil Company's Linda Morris 1-C in southern Lake County was temporarily suspended in December at a depth of 3130 ft. The top of the Paleozoic floor was logged at 2494 ft. Samples from the 636-ft. Paleozoic section consist of gray to white rather pure limestones, magnesian and dolomitic limestones, siliceous limestones, and a few fine to medium-grained sandstone beds. Calcite is a common constituent, but chert is rare. Several of the samples showed the presence of a green mineral, which may be altered serpentine.

TABLE 3.—*Physiographic Distribution of Wells Drilled in Tennessee in 1937*

Physiographic Division, *County*	Wild-cat	In Proven Fields	Oil Wells	Gas Wells
East Tennessee: *Bledsoe*	1	0	0	0
Cumberland Plateau: *Morgan*	0	1	1	0
Northeastern Highland Rim: *Clay*	18	2	9	1
Jackson	1	3	2	0
Overton	2	2	2	1
Pickett	1	1	2	0
Fentress	4	1	1	3
Eastern Highland Rim: *Moore*	2	0	0	0
Northern Highland Rim: *Sumner*	1	0	0	0
Central Basin: *Cannon*	1	0	0	0

The age of the Paleozoic rocks underlying the Upper Cretaceous sediments in the Mississippi embayment region of western Tennessee remains a problem. This is especially true in the Reelfoot Lake area, where pre-Cretaceous faulting probably has complicated the regional picture. Last year[1] a tentative Atoka age was assigned to the Paleozoic top in a test well in southwestern Obion County. During the past year considerable doubt has arisen as to possibilities of lower Pennsylvanian rocks in this well. It becomes increasingly evident that additional samples must be available from Paleozoic tests in the upper part of the Mississippi embayment before anything resembling definite correlations will be possible.

ACKNOWLEDGMENTS

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[1] K. E. Born: *Trans.* A.I.M.E. (1937) **123**, 453–454.

Development and Production in the East Texas District

By Wallace Ralston*

(New York Meeting, February, 1938)

During the year of 1937, the East Texas district produced 211,194,467 bbl. of oil and marketed more than 22,329 million cu. ft. of gas; 3377 oil and gas wells were completed. During this same period 106 exploratory wells were drilled, discovering three new oil fields and one gas-distillate field.

Fields

East Texas Field.—The East Texas field again led the district as to production and number of wells completed. During the year, 2420 oil wells were completed, making a total of 24,382 producing wells, which produced 171,336,854 bbl. of oil, for a total of 1,156,352,834 bbl. since the beginning. During the year the average bottom-hole pressure dropped 49 lb., making the average bottom-hole pressure 1119 lb. Approximately 3500 wells are making salt water, 20 per cent of them making over 80 per cent of the water. During the month of December, the daily average production of salt water was 119,000 barrels.

Talco Field, Titus and Franklin Counties.—The Talco field produced 9,780,948 bbl. of oil during the year, from 637 wells. During the year 472 wells were completed. All of the wells are pumping and 241 are making salt water. This field has followed a normal development and did not exceed the estimated number of acres reported last year.

Rodessa Field, Cass and Marion Counties.—The Rodessa field was extended about 13 miles southwest into Marion County, which added approximately 4000 acres to the field. During the year 260 wells were completed, making a total of 416 producing wells, which produced 12,646,970 bbl. of oil. The author was unable to obtain figures for the amount of gas produced. The field has two gasoline plants, which had a daily average of 16,558,000 cu. ft. of gas during December, averaging 0.83 gal. per M cu. ft. As of Jan. 1, 31 wells were making salt water. The bottom-hole pressure varies greatly, depending upon the pay from which the well is producing. The average bottom-hole pressure from the Young

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and Dees horizons in Cass County was 1701 lb. per sq. in.; for the Gloyd horizon, 2107 lb. per sq. in.; for the Henderson horizon, Marion County, 2677 lb. per sq. inch.

Van Field, Van Zandt County.—During the year 14 wells were completed, 13 in the Woodbine sand and 1 in the Nacatoch sand, for a total of 586 producing wells, which produced 11,402,510 bbl. of oil. As of Jan. 1, 30 wells were making salt water, 347 wells were flowing, and 239 were pumping.

Sulphur Bluff Field, Hopkins County.—The development of the Sulphur Bluff field was rather disappointing, as the limits have been reduced from 1500 acres to 800 acres. During the year 65 wells were completed, making a total of 73 producing wells. Of this number, 60 are pumping their production and approximately half are making salt water. During the year 1,599,808 bbl. of oil were produced, making total oil production 1,640,664 bbl. to the end of 1937.

Other Areas.—The other fields of the area followed normal development, as shown in Table 1.

TABLE 1.—*Oil and Gas Production in East Texas District*

Line Number	Field, *County*	Age, Years to End of 1937	Area Proved, Acres			
			Oil	Oil and Gas[a]	Gas	Total
1	Bethany, *Panola*	19	*y*		21,000	21,000
2	Boggy Creek, *Anderson-Cherokee*	10¾	200			200
3	Caddo, *Marion*	33	980			980
4	Camp Hill,[1] *Anderson*	3				
5	Carthage,[2] *Panola*	1⅙	*x*	*x*	*x*	*x*
6	Cayuga,[3] *Anderson-Henderson, Freestone*	3⅚	4,000		9,000	13,000
7	East Texas, *Rusk-Gregg-Smith, Cherokee and Upshur*	7⅓	133,000		2,000	135,000
8	Flagg Lake,[3] *Henderson*	1/12	*x*			*x*
9	Grapeland,[2] *Houston*	1⅓	*x*			
10	Joaquin,[2] *Shelby*	1¼	*x*	*x*	*x*	*x*
11	Kittrell, *Houston*	3⅓	160			160
12	Long Lake,[3] *Anderson-Leon*	4	*y*	*y*	*y*	15,700
13	Opelika,[2] Henderson	½	*x*	*x*	*x*	*x*
14	Percilla,[2] *Houston*	⅓	*x*			
15	Rodessa, *Cass and Marion*	2	10,884		4,000*x*	11,984*x*
16	Rusk, *Cherokee*	3½	200*x*			200*x*
17	Shell (Buffalo),[3] *Leon*	4				6,000*x*
18	Sulphur Bluff, *Hopkins*	1⅓	800			800
19	Talco, *Titus-Franklin*	1¾	10,000			10,000
20	Van, *Van Zandt*	8	4,521			4,521
21	Van (shallow), *Van Zandt*	5	200			200
22	Waskom, *Harrison*	13	*y*		7,500	7,500*y*

[a] Footnotes to column heads and explanation of symbols are given on page 313.

[1] Field depleted during October 1937. All wells plugged and abandoned.

[2] Not enough development to base reasonable estimate.

[3] These figures are more correct than previously shown.

EXPLORATORY DRILLING

During the year, 106 exploratory wells were drilled, discovering two new oil fields, one gas-distillate field and extending the Rodessa field approximately 13 miles into Marion County.

The extension of the Rodessa field was drilled by Overlees et al. on the Henderson tract, about 2 miles north of the town of Jefferson, in the R. Bennington survey. This well was drilled to a total depth of 6405 ft. in the Lower Glen Rose formation and later plugged back to 6005 ft., where it was completed making 87 bbl. of oil per day and 2,000,000 cu. ft. of gas. This well is on the same fault or fault zone as the Rodessa field. At present this area has not been definitely tied into the main Rodessa field, but the intervening area is gradually being proven.

The Procilla area is in the eastern part of north central Houston County. The discovery well was drilled by H. L. Hunt on the Elliot tract, in the J. M. Procilla survey. This well was drilled to a total depth of 6634 ft., stopping in the top of the Lower Cretaceous. It was then plugged back to 5870 ft., in the Woodbine formation, and completed making 15 bbl. of oil, 90 bbl. of salt water and 600,000 cu. ft. of gas.

TABLE 1.—(*Continued*)

Line Number	Total Oil Production, Bbl.				Total Gas Production, Millions Cu. Ft.				Number of Oil and/or Gas Wells		
	To End of 1937	During 1936	During 1937	Daily Average during Nov. 1937	To End of 1937	During 1936	During 1937	Maximum Daily during 1937	Completed to End of 1937	During 1937 Completed	During 1937 Abandoned
1	7,067*y*		7,067	37	111,331	4,491	3,312		*y*	3	0
2	4,651,031	190,398	153,273	353					33	0	0
3	7,592,783	29,676	33,187	116					81*y*	2	
4	286,178	132,786	27,399								
5									4	3	
6	7,326,650	2,156,095	3,294,377	10,200	27,681.8	5,365	*y*	40	240	70	*y*
7	1,156,352,834	165,270,636	171,336,854	456,499*x*	*y*	*y*	*y*	*y*	24,382	2,420	*y*
8	3,915		3,915						1	1	0
9									4	3	
10									4	3	
11	1,102,002	345,887	346,083	792					15	2	
12	1,048,200	415,000	491,200	1,550	20,488	5,943	8,352	*y*	74	41	3
13	1,109		1,109	3	*y*	*y*	*y*	*y*	2	2	0
14	12,152		12,152	65					1		
15	15,799,670	3,139,641	12,646,970	22,047	*y*	2.5	*y*	*y*	422	260	6
16	224,861	67,705	39,955	76					4	0	1
17									3		
18	1,640,664	40,856	1,599,808	6,017					73	65	
19	11,106,764	1,325,816	9,780,948	32,115					637	472	*y*
20	110,619,516	12,514,585	11,358,542	21,097					569	13	2
21	201,925	61,867	43,968	114					30	1	2
22	17,660*y*	*y*	17,660*y*	60	46,451	1,878	1,665	*y*	*y*	13*y*	*y*

Later testing showed a marked decrease of water and increase of oil, as it is now (January, 1938) making 65 bbl. of oil per day and about 45 bbl. of water. The structure is thought to be an anticline.

Opelika field is in the eastern portion of north central Henderson County. The first well was drilled by Tidewater, Seaboard and Humble oil companies on the McElreath & Suggett tract in the W. P. Wyche survey. The first well was completed in a porous zone in the anhydrite section of the Middle Glen Rose formation, at a total depth of 7195 ft., owing to a bad fishing job caused by the well's attempt to "blow out." The initial production of this well was 7 bbl. of oil per day. The second well, known as No. 2-C McElreath & Suggett, is 600 ft. southwest of No. 1, and was drilled to a total depth of 9320 ft. in the Travis Peak formation of Lower Cretaceous age. This well did not encounter the porous zone found in No. 1. Seven-inch casing was set at 9194 ft. and the hole plugged back to 9260 ft. A drill-stem test showed gas and no oil or water. The casing was then perforated between 8795 and 8890 ft. and again tested, showing gas and some distillate. The well was then plugged back to 8034 ft. and casing perforated from 7910 to 7950 ft., at

TABLE 1.—(*Continued*)

	Number of Oil and/or Gas Wells					Depth, Average in Feet		Oil Production Methods at End of 1937				Pressure, Lb. per Sq. In.[d]			Character of Oil, Approx. Average during 1937				
	At End of 1937							Number of Wells					Average at End of		Gravity A.P.I. at 60° F.				
Line Number	Temporarily Shut Down	Producing Oil Only	Producing Oil and Gas[b]	Producing Gas Only	Total Producing	Bottoms of Productive Wells	To Top of Productive Zone	Flowing	Pumping	Gas-lift	Miscellaneous	Initial	1936	1937	Maximum	Minimum	Weighted Average	Sulphur Per Cent	Base[e]
1	y	8		142	150	4,700[4]	1,000[4]		8										
2		21			21	3,666	3,632		21			650					38.5	0.24	P
3		34			34	2,366	2,300		34			x	x	x			40.0	y	P
4																			
5				4	4	6,000y						2,150y		2,150					
6		210		30	240	4,085	3,822	229	6	5		y	y	y			29	1.7	A
7	92	24,269		21y	24,290	3,665	3,632	18,863	5,021	385		e1,600±	e1,168	e1,119			39	0.25	
8	0	1			1	3,105	3,097	1				y					44.8	y	P
9	4				4	6,025	5,975					y	y	y					
10	4				4	5,011	4,890					2,525y		2,525y					
11		14			14	2,013	1,995		14			700					24	0.1	P
12		46		28	74	5,250	5,170	71	1	2		y	y	y			40	0.24	P
13			2		2	8,890	7,195	2				y					57	y	P
14					1	5,670	5,665	1				y	y	y			41	y	P
15		397		19	416	6,020	5,960	349	6	32	1	e,2800	e1,967	y			43	0.18	P
16	0	3			3	5,125	5,120		3			y					42	y	P
17	3					5,695	5,285					y	y	y					
18	7	73			73	4,520	4,480	13	60			y	y	y			22.5	2.8	M
19		637			637	4,320	4,200	637				y	y	y			22	2.8	M
20	8	556			556	2,950	2,500	347	209	0	0	e1,230	e1,148	e1,137	36	32	34	0.8	P
21		30			30	1,200	1,130	0	30	0	0	x	y	y	32	30	31	1.16	P
22	y	17	y	y	101	4,650	1,000		17			y					y	y	y

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[4] Figures for top and bottom of producing zone are from top of highest pay to bottom of lowest pay; six or more zones are in this interval.

which depth it was completed as a gas-distillate well. The Railroad Commission test showed 300 bbl. of distillate and 9 million cubic feet of gas on ⅜-in. tubing choke. The structure is an anticline with some faulting.

Flag Lake area is in the western part of Henderson County, on the Mexia-Powell fault zone. The discovery well was drilled by Sherman Hunt et al. on the Dillard tract, in the H. Jeffreys survey, on a faulted structure of the Mexia-Powell type. Several wells had previously been drilled in this area, testing the Woodbine sand; although shows of oil were encountered, none of the wells were completed as commercial oil wells. This test was drilled to test the Lower Glen Rose. In coring the Woodbine section a few pieces of oil-saturated sand were recovered. The Glen Rose and Paluxy section was found to carry no oil or gas. Casing was cemented at 3622 ft. After running Schlumberger, it was decided to test the thin oil sand indicated at 3095 to 3105 ft. On a 3⁄16-in. tubing choke this well made 127 bbl. of oil and no water.

SUMMARY AND OUTLOOK FOR 1938

Several important exploratory wells will probably be drilled to test for deep production. Because of the high cost of drilling deep wells in

TABLE 1.—(*Continued*)

Line Number	Character of Gas, Approx. Average during 1937		Producing Rock						Number of Dry and/or Near-dry Holes to End of 1937	Deepest Zone Tested to End of 1937	
	B.t.u. per Cu. Ft.	Gal. Gasoline per M Cu. Ft.	Name	Age[f]	Character[g]	Porosity[h]	Net Thickness, Average in Feet	Structure[i]		Name	Depth of Hole, Feet
1	1,000	*y*	Various zones	CreU, L	S, L	*y*	*x*	A	39*y*	Sub-anhydrite CreL	5,860
2			Woodbine	CreU	S	25	±34	DS	43	Fredericksburg CreL	4,648
3			Tokio	CreU	S	20±	15	A	*y*	*y*	*y*
4											
5	*y*	*y*	Glen Rose	CreL	LS	*y*	*y*	A	1	Lower Marine Pre Cre?	8,718
6	*y*	*y*	Woodbine	CreU	S	25	30	A	8	Travis Peak CreL	9,085
7	*y*	3.5	Woodbine	CreU	S	25	30±	MU	*y*	Washita CreL	3,894
8			Woodbine	CreU	S	*y*25	6	AF	7	Travis Peak CreL	6,495
9	*y*	*y*	Woodbine	CreU	S	25	40	A	1	Woodbine CreU	6,250
10			Glen Rose	CreL	LS	*y*	*y*	A		Glen Rose	5,126
11			Reklaw	Eoc	S	*y*	12	DS	9	Wilcox Eocene	3,870
12	1,030	0.85	Woodbine	CreU	S	25	25	A	5	Travis Peak CreL	9,966
13			Glen Rose	CreL	LS	*y*	*x*	A		Travis Peak CreL	9,320
14			Woodbine	CreU	S	*y*	5*y*	A	0	Del Rio CreL	6,634
15	*y*	0.83	L. Glen Rose	CreL	L, S	±17	15	AF	10	Salt-below L. Marine	11,484
16			Woodbine	CreU	S	20	5	MU	6	Woodbine CreU	5,302
17			Woodbine	CreU	S	11	30	A	3	Washita CreL	6,140
18			Paluxy	CreL	S	20	40	AF	*y*	Travis Peak CreL	6,600
19			Paluxy	CreL	S	20	50	AF	*y*	L. Glenrose CreL	5,679
20	1,100	2.5	Woodbine	CreU	SH	25	268	AF	68	Trinity	7,501
21			Nacatoch sand	CreU	S	*y*	20	AF	17	Trinity	7,501
22	1,000	*y*	Various	CreU, L	S, L	*y*	*x*	A	16*y*	Glen Rose CreL	4,980

this area, there will probably be fewer exploratory wells than in the year of 1937.

ACKNOWLEDGMENTS

Various sources were used in compiling the data used in this report. Thanks for information are due to many persons; especially to Mr. Frank E. Poulsen, Pure Oil Co., for data on the Van field, and to Mr. M. Schwartz, of the Seaboard Oil Corporation, for data on Cayuga and Long Lake fields; also to various members of the Sun Oil Company's technical staff for other data.

TABLE 2.—*Summary of Drilling Operations in East Texas District*

Important Wildcats Drilled in 1937

	County	Location Survey	Total Depth, Ft.	Surface Formation	Deepest Horizon Tested
1	Marion	R. Bennington	6,405	Wilcox	L. Glen Rose CreL
2	Houston	J. M. Procilla	6,634	Mt. Selman	Woodbine CreU
3	Henderson	W. P. Wyche	9,320	Mt. Selman	Travis Peak CreL
4	Henderson	H. Jeffreys	6,518	Midway	Travis Peak CreL

Important Wildcats Drilled in 1937

	Drilled by	Initial Production per Day		Choke, Fractions of an Inch	Pressure, Lb. per Sq. In.		Remarks
		Oil, U. S. Bbl.	Gas, Millions Cu. Ft.		Casing	Tubing	
1	Overlees et al.	87	2.0	(2)—1/32	2,450	?	P.B. 6005
2	H. L. Hunt	15	0.6	1/4	1,600	1,600	P.B. 5870
3	Tidewater Seaboard and Humble	300 dist.	9.0	3/8	3,300	3,300	P.B. to 8038
4	Sherman Hunt et al.	127		3/16	105	100	P.B. to Woodbine

	In Proven Fields	Wildcats
Number of wells drilling Dec. 31, 1937	196	16
Number of oil wells completed during 1937	3,374	3
Number of gas wells completed during 1937	y	1
Number of dry holes completed during 1937	75	102

Oil and Gas Production on the Texas Gulf Coast during 1937

By E. P. Hayes* and J. K. Butler,* Junior Member A.I.M.E.

Oil and gas development has continued unabated on the Texas Gulf Coast during 1937. Although the number of important new discoveries has not been great, the extensions in older fields, owing to discovery of new sands and the lateral extension of known sands, has been extensive. Twenty-four new producing fields were added during the year, and many of these areas give promise of developing into important producing districts in the future. Alta Mesa, Amelia, Aransas, Clara Driscoll, Five Corners, Hamman, Heyser, Old Ocean, Premont, Seabreeze, Segno and West Columbia have all had major extensions during 1937.

The 1937 production for the Texas Gulf Coast was 120,141,429 bbl., or 32+ per cent increase over the 1936 production of 90,865,293 bbl.† The total number of producing wells has increased from 6727 to 8968. Well abandonments have been few and indications are that they will continue to be so. Rigid proration has been and continues to be in effect, and, as a result, wells in the Gulf Coast will have prolonged life.

New Fields

Tables 1 and 2 contain general information on all fields in this district. The following named fields were discovered in 1937:

Aransas County.—Barnsdall Oil Company's No. 1-A Edwards was the discovery well for the Lamar field. It was drilled to a total depth of 9785 ft., plugged back and completed at 7530 ft. in the Frio as a gas and distillate well. Present indications are not very promising for a major field.

Bee County.—The McMurray (Strauch) field was discovered by Dirks Bros. No. 1 Strauch at a total depth of 4577 ft. This is a Yegua producer, and had an initial production of 230 bbl. on a 3/16-in. choke.

Brazoria County.—The Sandy Point field was discovered by Henry DeArman's No. 1 Fite, which was completed as a producer at 6501 ft. in the Marginulina-Frio series.

Galveston County.—Although the Hitchcock field was discovered in 1936, the first commercial oil producer was completed in 1937 when

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* Producing Department, The Texas Company, Houston, Texas.

† Will not check last year's figure, because of elimination of fields now shown in other districts.

TABLE 1.—*Oil and Gas Production on Texas Gulf Coast during* 1937

Line Number	Field, *County*	Age, Years to End of 1937	Area Proved, Acres				Total Oil Production, Bbl.		
			Oil	Oil and Gas[a]	Gas	Total	To End of 1937	During 1936	During 1937
1	Agua Dulce, *Nueces*	8	0	500	9,500	10,000	310,928	39,422	69,698
2	Allen, *Brazoria*	11	10	0	0	10	84,925	3,228	3,364
3	Alta Mesa, *Brooks*	2	280	0	60	340	164,070	6,115	157,955
4	Alta Verde, *Brooks*	2	50	0	0	50	3,115*y*	*y*	3,115
5	Amelia, *Jefferson*	2	2,000	0	0	2,000	1,727,885	204,195	1,523,690
6	Anahuac, *Chambers*	3	5,650	0	0	5,650	7,244,427	2,603,280	4,279,108
7	Angelita, *San Patricio*	4	40	0	0	40	30,924	86*y*	348
8	Aransas, *Aransas, San Patricio*	2	1,000	0	20	1,020	941,860	36,688	905,172
9	Arriola, *Hardin*	6	100	0	0	100	1,681,688	390,981	217,275
10	Baldwin, *Nueces*	3	270	0	0	270	459,755	234,409	148,227
11	Barbers Hill, *Chambers*	22	515	0	0	515	60,041,401	5,471,266	4,480,222
12	Shallow	22	70			70	1,735,214	0	0
13	Deep	10	445			445	58,306,187	5,471,266	4,480,222
14	Batesville, *Zavalla*	1	40	0	0	40	11,757		11,757
15	Batson, *Hardin*	35	597	0	0	597	38,250,560	653,484	637,103
16	Bay City (Van Vleck), *Matagorda*	4	500	0	0	500	1,089,225	382,812	665,527
17	Big Creek, *Ft. Bend*	16	200	0	0	200	9,363,760	392,975	379,810
18	Big Hill, *Jefferson*	15	10	0	0	10	13,853	Prod. depleted 1924	
19	Big Hill, *Matagorda*	34	15	0	0	15	210,906	Prod. depleted 1907	
20	Blue Ridge, *Ft. Bend*	19	325	0	0	325	10,581,746	526,740	360,931
21	Boling, *Ft. Bend, Wharton*	13	200	0	0	200	5,629,669	347,871	563,957
22	Brenham, *Austin, Washington*	23	55	0	0	55	346,061	9,117	7,053
23	Brookshire, *Waller*	4	50	0	0	50	19,382	2,856	5,884
24	Buckeye, *Matagorda*	6	50	0	0	50	646,207	71,111	51,461
25	Burnell, South, *Karnes*	1	400	0	210	610	124,413		124,413
26	Caesar, *Bee*	4	285	0	175	460	735,557	319,159	136,816
27	Call, *Newton*	1	100	0	0	100	5,567		5,567
28	Captain Lucey, *Jim Wells*	2	0	170	0	170	297,789	113,223	184,566
29	Chapman, *Nueces*	1	50	0	0	50	28,312		28,312
30	Cheek, *Jefferson*	1	40	0	0	40	21,037		21,037
31	Clam Lake, *Jefferson*	1	20	0	0	20	1,235		1,235
32	Clay Creek, *Washington*	10	300	0	0	300	3,951,533	398,609	300,949
33	Cleveland, *Liberty*	4	400	0	0	400	928,001	303,356	210,502
34	Clinton, *Harris*	2	20	20	0	40	3,899	2,996	903
35	Colleto Creek, *Victoria*	4	0	350	350	700	729,424	269,336	239,617
36	Conroe, *Montgomery*	6	19,000	0	0	19,000	86,874,068	14,905,462	15,016,701
37	Corpus Christi, *Nueces*	3	1,500	0	0	1,500	4,926,115	2,223,958	2,692,822
38	Cotton Lake, *Chambers*	2	200	0	0	200	394,463	43,029	351,434

[a] Footnotes to column heads and explanation of symbols are given on page 313.

TABLE 1.—(*Continued*)

Line Number	Total Oil Production, Bbl.	Total Gas Production, Millions Cu. Ft.				Number of Oil and/or Gas Wells								Depth, Average in Feet
							During 1937		At End of 1937					
	Daily Average during Nov. 1937	To End of 1937	During 1936	During 1937	Maximum Daily during 1937	Completed to End of 1937	Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Oil and Gas[5]	Producing Gas Only	Total Producing	Bottoms of Productive Wells
1	304		3,522	6,044		y	y	y	y	0	y	46	46y	2,005[4] 4,820[4]
2	11					5	0	0	0	1			1	5,030
3	407			242		18	14	0	2	13		3	16	1,140[4] 2,475 4,547
4	2					5	1	0	1	4			4	926
5	6,254			76		145	128	0	2	139		4	143	5,400 6,780
6	9,381		79	90		237	92	0	4	226		7	233	7,085
7	0					2	0	1	1	0			0	5,380
8	4,321	779	156	623		98	92	1	2	94		1	95	7,100
9	520			7		15	0	0	1	12			12	4,400
10	320		39	36		9	0	0	0	8		1	9	3,877 4,069
11	10,659					401	3	3	8	161			161	4,500
12	0													2,300
13	10,659					401	3	3	8	161			161	5,200
14	27					1	1	0	0	1			1	3,948
15	1,557					996x	2	0	10	200			200	1,250 5,000
16	1,219		144	149		23	4	0	0	23			23	7,075 7,495
17	839					82	6	0	3	27			27	3,850
18						5	1	0	1	0			0	2,500
19						3	0	0	0	0			0	862
20	841					185	5	0	3	59		1	60	3,600
21	1,545		7	19		162	6	y	y	91			91	1,375
22	30					63	1	y	y	34	y	2	36	225
23	6					1	0	0	0	1			1	2,974
24	181			17		2	0	0	0	2			2	7,926
25	971		530	761		32	26	0	1	25		6	31	3,350[4] 3,650
26	328		15			41	1	0	3	27		7	34	3,055
27	24	2		2		1	1	0	0	1			1	6,918
28	354	935	14	921		17	3	0	1	6		9	15	4,000[4] 5,370
29	36					2	2	0	0	2			2	5,058 6,484
30	320	11		11		2	2	0	0	2			2	8,565
31	0					1	1	0	0	1			1	5,929
32	603		137	275		66	1	0	3	50		3	53	1,250
33	439					22	5	1	4	11		3	14	5,900
34	0	591	12	579		3	2	0	1	1		1	2	3,735 8,101[7]
35	496		675	10		28	0	0	0	20		4	24	2,226[4] 2,835
36	36,836	62,195	104	272		963	17	1y	11y	947		3	950	5,150
37	5,319					247	42	0	31y	211		5	216	4,096
38	1,057					20	12	0	1	17		1	18	6,310 6,520

[4] Gas.
[7] Distillate.

TABLE 1.—(*Continued*)

Line Number	Depth, Average in Feet	Oil Production Methods at End of 1937			Pressure, Lb. per Sq. In.[d]			Character of Oil, Approx. Average during 1937					Character of Gas, Approx. Average during 1937	
		Number of Wells				Average at End of		Gravity A.P.I. at 60° F.						
	To Top of Productive Zone	Flowing	Pumping	Gas-lift	Initial	1936	1937	Maximum	Minimum	Weighted Average	Sulphur, Per Cent	Base[e]	B.t.u. per Cu. Ft.	Gal. Gasoline per M Cu. Ft.
1	1,998 4,804				800 1,650	700*y* 1,500*y*				59	0.02	M		
2			1		200			41.3	28.3	34.3	0.11	A		
3	1,100 2,450	12	1		500[4] 100	500 100		25.2	24.8	25	0	P		
4	916	2	2		100	*y*				26.2	*y*	P		
5	6,745	139			675[5]	650				29.3	*y*	A		
6	7,000	225		1	e3,260	e3,190	1,250	35.1	34.7	34.9	0	M		
7	5,370				1,140					33.7	0.13	A		
8	6,500	94			2,200	1,975	1,600	54	40	44	*y*	P		
9	2,990	2	10		440			42	27	34	0.13	A		
10			8		225					25.8	*y*	M		
11		32	129					34	24.8	26	0.21	A		
12					*x*									
13		32	129		296	e1,565		34	24.8	26	0.21	A		
14	3,941		1							16.6	*y*	*y*		
15		4	196		*x*			40	20	27.7	*y*	A		
16	7,020	23			1,700			56	40	48	*y*	M		
17			27		400			42.7	19.5	28	*y*	A		
18					*x*		0			*x*	*x*	A		
19					*x*		0			*x*	*x*	A		
20		3	56		385			45	20	26	0.25	A		
21		43	48					33.7	21.3	28.3	0.41	A		
22			34					19	14	17	*y*	A		
23	2,955		1		100		0			24	*y*	A		
24	7,831	2			1,045					38	0.07	A		
25		24	1		1,425					*y*	*y*	*y*		
26	3,040	3	24		1,140 315					26.4	*y*	M		
27	6,908	1			1,475		1,450			39.6	*y*	*y*		
28	5,350	4	2		200[5]	200[6]				38.9	*y*	M		
29	5,046 6,464	1	1		675		675			41.9	*y*	*y*		
30		2			2,950		2,050			43.9	*y*	*y*		
31	5,913	1			1,600		1,600			34.2	0.2*y*	*y*		
32		5	45		350			27	23	26	0.36	A		
33	5,700	11			2,400		1,800	45	38	40	*y*	A		
34	8,100		1		4,800	3,200				48	*y*	M		
35		19	1					32.5	20	25	*y*	A		
36	5,000	920	27		e2,275	e2,076				38	0.05	M	1,132	100
37	4,076	163	48		1,650					23.3	*y*	M		
38	6,302	17			550[5]	550[6]				28	*y*	A		

TABLE 1.—(*Continued*)

Line Number	Producing Rock						Number of Dry and/or Near-dry Holes to End of 1937	Deepest Zone Tested to End of 1937	
	Name	Age[f]	Character[g]	Porosity[h]	Net Thickness, Average in Feet	Structure[i]		Name	Depth of Hole, Ft.
1	Fleming Frio	Mio Olig	SH SH	30	10 16	DF	*y*	Vicksburg	9,003
2	Mio	Mio	SH	Por	10	Ds	30	Miocene	5,958
3	Mio	Mio	Ss	Por	20	D	13	Vicksburg	8,022
4	Mio	Mio	S	Por	10	D	13	Yegua	5,096
5	Frio	Olig	Ss	Por	15	D	20	Vicksburg	8,501
6	Frio	Olig	Ss	Por	60	Df	17	Frio	8,749
7	Frio	Olig	Ss	Por	14	Nf	6	Frio	7,131
8	Marginulina, Frio	Olig	Ss	25–34	15	N*y*	2	Frio	8,889
9	Mio, Frio	Mio Olig	Ss	Por	50±	Ds	10	Yegua	6,743
10	Mio	Mio	S	Por	12	AF	7*y*	Frio	6,610
11					75*x*	Ds	144	McElroy	8,148
12	Pli, Mio	Pli Mio	Ss	Por	42*x*				
13	Mio, Frio	Mio Olig	Ss	Por	80*x*				
14	Edwards lime	CreU	L	Cav	6	MF	0	Edwards lime	3,948
15	Cap Rock, Lissie, Lagarto Mid-Olig, Yequa	Pre-Ter Plio, Mio Olig, Eoc	L, Ss	Cav Por	74*x*	Ds	83*x*	Crockett	4,980
16	Marginulina-Frio	Olig	SH	Por	21	D	4	Vicksburg	11,286
17	Pli, Mio, Mid-Olig Frio	Pli, Mio, Olig	SH	Por	54	Ds	64	Jackson	5,536
18	Pli, Mio	Pli, Mio	S	Por	10	Ds	58	Marginulina	6,742
19	Cap rock, Mio	Pre-Ter Mio	L*x*	Cav Por	*x*	Ds	5	*x*	3,000*x*
20	Mio, Mid-Olig, Frio	Mio-Olig	SH	Por	60	Ds	112	Jackson	6,189
21	Cap rock Mid-Olig, Frio	Pre-Ter Olig	L, SH	Cav Por	60	Ds	75	Vicksburg	5,546
22	Oakville, Cockfield	Mio Eoc	SH	Por	10*x*	Ds	67*x*	Carrizzo	3,930
23	Frio	Olig	Ss	Por	16	D	10*y*	Hockleyensis	7,215
24	Frio	Olig	SH	Por	60	D	6	Frio	10,503
25	Cockfield (Pettus)	Eoc	Ss	Por	12	DF	3	Yegua	5,280
26	Cockfield (Pettus)	Eoc	Ss	Por	15	DF	19	Yegua	4,502
27	Cockfield	Eoc	S	Por	7	NF	3	Yegua	7,380
28	Heterostegina Frio	Olig	Ss	Por	20	MF	11	Frio	6,500
29	Catahoula Frio	Mio Olig	Ss	Por	8	ML	4	Frio	7,012
30	Vicksburg	Eoc	S	Por	10	NF	1	Vicksburg	8,841
31	Mio	Mio	Ss	Por	15	D	1	Miocene	5,929
32	Claiborne, Wilcox	Eoc	SH	Por	120	Ds	57	Wilcox	8,306[6]
33	Cockfield, Yegua	Eoc	Ss	15	8	MF	9	Cook Mt.	8,734
34	Mio, Cockfield	Mio, Eoc	Ss	Por	*x*	D	2	Cockfield	8,101
35	Catahoula, Frio	Mio, Olig	Ss	Por	10	MF	16	Frio	5,368
36	J. Cockfield Conroe	Eoc	Ss	27*x*	14 56	D	55	L. Saline Bayou	8,011
37	Catahoula	Mio	S	Por	10*x*	A	11	Frio	7,531
38	Marginulina	Olig	Ss	Por	8	Df	7	Frio	7,302

[6] In salt.

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Age, Years to End of 1937	Area Proved, Acres				Total Oil Production, Bbl.		
			Oil	Oil and Gas[a]	Gas	Total	To End of 1937	During 1936	During 1937
39	Damon Mound, *Brazoria*	23	270	0	0	270	9,328,476	179,215	133,125
40	Danbury, *Brazoria*	8	100	0	20	120	14,267		9,668
41	Dickinson, *Galveston*	4	0	4,300	0	4,300	2,889,277	947,171	1,645,291
42	Dinero, *Live Oak*	3	0	50	20	70	54,836	20,786	5,674
43	Dirks, *Bee*	4	865	0	0	865	3,645,252	1,710,812	1,285,928
44	Driscoll, Clara, *Nueces*	3	500	0	0	500	467,836	84,322	378,685
45	East Chittim, *Maverick*	1	40	0	40	80	657		657
46	East Premont, *Jim Wells*	1	20	0	0	20	1,000*y*		1,000*y*
47	Edinburg, *Hidalgo*	3	0	100	0	100	500	0*y*	0*y*
48	Edna, *Jackson*	17	0	20	105	125	0	0	0[2]
49	Esperson, *Liberty*	9	400	0	0	400	4,787,172	632,771	600,514
50	Ezzell, *Live Oak, McMullen*	1	300	0	0	300	112,225		112,225
51	Fannett, *Jefferson*	11	90	0	0	90	2,205,228	329,714	289,348
52	Five Corners, *Wharton*	2	200	0	600	800	54,408	1,746	52,662
53	Flour Bluff, *Nueces*	2	2,500	0	0	2,500	1,715,890	94,357	1,621,533
54	Fort Merrill, *Live Oak*	3	50	0	0	50	27,276	15,097	2,148
55	Ganado, *Jackson*	1	0	60	0	60	11,511		11,511
56	Garwood, *Colorado*	5	10	10	0	20	2,024	Prod. depleted 1933	
57	Green's Lake, *Galveston*	2	50	0	20	70	29,440	19,332	10,108
58	Greta, *Refugio*	5	5,414	0	1,050	6,464	19,873,377	5,381,404	4,652,813
59	Goose Creek, *Harris*	30	910	0	0	910	76,112,233	978,726	861,674
60	Hamman, *Matagorda*	2	140	0	0	140	190,987	38,201	152,786
61	Hankamer, *Liberty*	9	420	0	0	420	4,881,431	779,294	573,192
62	Hardin, *Liberty*	3	350	0	20	370	428,172	134,778	238,069
63	Hartzendorf, *Bee*	3	20	0	0	20	Prod. included with Pettus		
64	Hastings, *Brazoria, Galveston*	4	4,500	0	0	4,500	8,921,564	2,420,930	5,867,819
65	Hawkinsville, *Matagorda*	2	50	0	0	50	3,616	3,345	271
66	Heyser, *Calhoun, Victoria*	2	3,100	0	0	3,100	1,692,934	138,992	1,553,942
67	High Island, *Galveston*	16	200	0	0	200	14,296,916	2,066,254	1,184,610
68	Hitchcock, *Galveston*	2	40	0	20	60	19,181		19,181
69	Hockley, *Harris*	15	10	0	0	10	23,404	Prod. depleted 1935	
70	Holzmark, *Bee*	3	80	0	20	100	17,310	3,659	13,316
71	Hords Creek, *Goliad*	3	100	0	50	150	30,576	16,766	9,648
72	Hoskins Mound, *Brazoria*	34	10	0	0	10	31,755	Prod. depleted 1907	
73	Hull, *Liberty*	20	750	0	0	750	84,464,019	1,956,507	2,526,292
74	Shallow	20	650			650	78,171,198	1,079,311	729,450[1]
75	Deep	5	100			100	6,292,821	877,196	1,796,842[1]
76	Humble, *Harris*	33	2,400	0	0	2,400	122,607,491	1,196,159	1,271,618
77	Shallow	33	2,200			2,200	109,577,947	569,200[1]	606,500[1]
78	Deep	9	200			200	13,029,544	626,959[1]	665,118[1]
79	Joe's Lake, *Tyler*	1	300	0	0	300	74,310		74,310
80	Keeran, *Victoria*	6	350	0	40	390	667,369	112,486	202,162
81	Kingsville, *Kleberg*	12	90	0	175	265	685,529	21,659	25,177

[1] Estimated.
[2] Production used to develop field.

TABLE 1.—(*Continued*)

Line Number	Total Oil Production, Bbl.	Total Gas Production, Millions Cu. Ft.				Number of Oil and/or Gas Wells								Depth, Average in Feet
							During 1937		At End of 1937					
	Daily Average during Nov. 1937	To End of 1937	During 1936	During 1937	Maximum Daily during 1937	Completed to End of 1937	Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Oil and Gas[5]	Producing Gas Only	Total Producing	Bottoms of Productive Wells
39	384					129	1	0	3	30			30	2,700
40	105			72		6	3	0	1	2		1	3	1,970
41	5,673		1,814	4,960		118	54	0	11*y*	94		7	101	8,050 9,120
42	17		41			4	0	0	1	2		1	3	5,220
43	3,093					100	0	0	1	98			98	3,875
44	932					25	18	0	2	20		3	23	3,816
45	10		1,143	1,305		4	2	0	1	1		2	3	3,287 5,567[4]
46	0					1	1	0	0	1			1	6,595
47	0					1*y*	0	0	1	0			0	6,770
48	0		406	2,124		13	1	*y*	*y*	*y*	*y*	2*y*	2*y*	4,655
49	1,304					56	7	1	0	47		2	49	2,300 4,100
50	1,054					55	55	0	0	51		4	55	1,520
51	685					26	2	0	1	19			19	4,000 6,580
52	171	788	161	627		10	7	0	0	6		4	10	5,550
53	4,953					99	83	0	1	97		1	98	6,665
54	9					2	0	0	1	1			1	4,643
55	82	47		47		3	3	0	0	2		1	3	5,112
56						4	2	1	1	0			0	6,100
57	18			25		3	1	2	0	1			1	4,000
58	9,461		3,135	2,729		229	9	0	6	208		14	222	2,100[4] 3,500 5,900
59	1,845					867	1	*y*	*y*	97			97	1,000 4,600
60	735					7	6	0	0	7			7	8,182 9,183 9,370
61	1,222					45	5	0	6	32		2	34	2,700 5,700
62	1,317			166		17	16	0	0	16		1	17	7,690
63						1	*y*	*y*	*y*	*y*			*y*	3,651
64	18,935		419	2,213		453	329	0	0	453			453	6,100
65	0					1	0	0	1	0			0	5,160
66	6,028		150			106	88	0	0	106			106	4,876 5,475
67	2,382					105	8	13	3	60		1	61	4,600 6,200
68	147					3	2	1	0	2			2	5,134
69						3	0	0	0	0			0	2,250
70	29		15	26		6	1	0	2	3		1	4	4,064 4,075
71	27					5	0	0	2	1		1	2	4,575
72						14	0	0	0	0			0	623
73	8,466					743	11	*y*	0	184			184	2,900
74	2,450					*y*	*y*	*y*		*y*			*y*	2,200
75	6,016					*y*	*y*	*y*		*y*			*y*	4,650
76	3,172					1,714	29	*y*	*y*	295			295	
77	1,519[1]					*y*	*y*			*y*			*y*	700[3]
78	1,653[1]					*y*	*y*			*y*			*y*	5,670
79	321		30	17		5	5	0	0	5			5	7,700
80	614		82	155		16	8	0	0	12		1	13	5,860
81	64		97	121		20	1	*y*	*y*	11		3	14	2,350 3,238

[3] Cap rock.

TABLE 1.—(*Continued*)

Line Number	Depth, Average in Feet	Oil Production Methods at End of 1937			Pressure, Lb. per Sq. In.[d]			Character of Oil, Approx. Average during 1937					Character of Gas, Approx. Average during 1937	
	To Top of Productive Zone	Number of Wells			Initial	Average at End of		Gravity A.P.I. at 60° F.			Sulphur, Per Cent	Base[e]	B.t.u. per Cu. Ft.	Gal. Gasoline per M Cu. Ft.
		Flowing	Pumping	Gas-lift		1936	1937	Maximum	Minimum	Weighted Average				
39		1	29		x			33	21	26	0.37	A		
40	1,955 7,980	1	1		500		500	23	21	23	0.25	A		
41	9,080	92		2	1,250[5]	1,250	1,250	54	35	37.5	0.07	M		
42	5,200	2			1,600					44.2	y	A		
43	3,859	56	42			100				45	y	M		
44	3,807	16	4		750					23.8	y	M		
45	{ 3,255		1		0		0			42.5	y	y		
46	6,585	1			y		y			36.5	y	y		
47	6,685									y	y	y		
48	4,640	y								y	y	y		
49		6	41		100			26	22	24	0.26	A		
50		6	45		420					19.7	y	y		
51	{ 3,650 6,550 }	3	16		540			30	25	28	y	A		
52	5,540	5		1	2,350	2,350	2,350			25.6	0	A		
53	6,590	96		1	1,420	1,420	1,400	45	42	43.4	y	P		
54	4,637		1		1,100		0			46	y	Ay		
55	5,087	2			1,625	1,625	e2,200			26	y	y		
56					1,225					44	x	M		
57	3,880		1		1,300	1,300		39	21	26.5	0.14	P		
58	{ 2,000 3,470 5,900 }	189	17	2	1,350	875		39	23	24	0.20	A		
59			97					30	20	25.5	0.19	A		
60		7			800[5]					37	y	M		
61	{ 2,550	8	24		424			26	15.7	23.4	0.33	A		
62	7,665	16			900					36.3	y	Ay		
63	3,642									45	y	M		
64	5,600	449		4	2,175	2,175	2,100	32	30	31	y	M		
65	5,150				200[5]		0			30.4	y	Ay		
66	{ 5,400y	106			880	880		33	31.4	32.3	y	M	1,000	
67		21	39		527			39	23	33	y	A		
68	5,118	2			880	880		42	31	35.8	0.04	A		
69	2,220				40		0	37	22	32	x	A		
70		3			1,050					y	y	y		
71		1			1,550					47.6	y	Ay		
72	600				x					x	x	A		
73		18	166					41	17	32.7	0.28	A		
74		y	y		x			38	15.5	30				
75		y	y		530			41	36	38				
76		9	286		x			52	18	26.5	0.11	A		
77		y	y											
78		y	y											
79	7,641	5			1,425		1,425			45.8	y	y		
80	5,850	11	1		{ 2,400[4] 1,450		2,085 }	48	28	37	y	A		
81	{ 2,050 3,217 }	3	8					26		21.5	0.14	A		

[5] Flowing pressure through tubing on small choke.

TABLE 1.—(*Continued*)

Line Number	Producing Rock							Deepest Zone Tested to End of 1937	
	Name	Age[f]	Character[g]	Porosity[h]	Net Thickness, Average in Feet	Structure[i]	Number of Dry and/or Near-dry Holes to End of 1937	Name	Depth of Hole, Ft.
39	Mio, Mid-Olig Vicksburg	Mio Olig	SH	Por	43*x*	Ds	180	*y*	8,112[6]
40	Pli, Mio	Pli-Mio	Ss	Por	20	Ds	14	Olig	7,495
41	Frio	Olig	Ss	Por	12	DF	12	Frio	9,463
42	Yegua	Eoc	S	Por	7*y*	D	4	Cook Mt.	5,913
43	Cockfield (Pettus)	Eoc	Ss	Por	16	DF	11	Yegua	4,776
44	Catahoula	Mio	S	Por	10	Df	8	Frio	6,138
45	Edwards lime	CreU	L	Cav	20	F	7	Trinity	7,635
46	Frio	Olig	Ss	Por	10	D	0	Vicksburg	8,162
47	Frio	Olig	SH	Por	20*y*	D	0*y*	Frio	7,508
48	Frio	Olig	Ss	Por	15*y*	D	9	Cockfield	7,180
49	Mio Heterostegina	Mio Olig	Ss	24	15	Ds	30	Weches Crockett	8,926 9,375[6]
50	Hockleyensis (Loma Novia)	Eoc	Ss	Por	8	D	10	Hockleyensis	2,005
51	Mio Mid-Olig, Frio	Mio Olig	Ss	20	20	Ds	36	Vicksburg	7,293
52	Marginulina	Olig	Ss	Por	8	D	1	Frio	6,511
53	Frio	Olig	Ss	Por	100±	D	6	Frio	7,504
54	Yegua	Eoc	S	Por	5	D	1	Crockett	5,425
55	Marginulina	Olig	Ss	Por	5	D	2	Frio	6,544
56	Yegua	Eoc	S	Por	12	D	12	Yegua	6,777
57	*y*	Pli, Mio	Ss	Por	15	*y*	7	Frio	9,636
58	Catahoula Heterostegina-Frio	Mio Olig	Ss	20 33	20[4] 18	A	17*y*	Vicksburg	7,461
59	Pli, Mio, Mid-Olig Frio, Vicksburg	Pli, Mio Olig	SH Ss	Por	40	D	265	McElroy	6,975
60	Frio	Olig	S	Por	10	Ds	1	Frio	9,575
61	Mio, Frio	Mio Olig	Ss	20	29	Ds	16	Dibol	7,681
62	Yegua	Eoc	S	Por	20	D	8	Yegua	8,110
63	Cockfield (Pettus)	Eoc	SH	Por	9	A	1	Yegua	3,872
64	Frio	Olig	Ss	Por	60	D	13	Vicksburg	8,792
65	Mio	Mio	SH	Por	10	D	17	Oligocene	6,326
66	Heterostegina Frio	Olig	Ss	25	25	A	10	Frio	6,505
67	Pli, Mio Mid-Olig	Pli, Mio Olig	Ss SH	Por	35*x*	Ds	115	Mid-Olig	6,275
68	Mio	Mio	Ss	Por	16	D	2	Frio	10,460
69	Cap rock, Frio	Pre-Ter Olig	L, SH	Cav Por	30	Ds	65	Yegua	7,481
70	Cockfield (Pettus)	Eoc	Ss	Por		NF	8	Yegua	4,458
71	Yegua	Eoc	SH	Por	10	MF	10	Cook Mt.	6,004
72	*y*	*y*	SH	Por	*x*	Ds	39	Salt	1,150*x*
73						Ds	218	Cook Mt.	6,845
74	Pli, Mio, Mid-Olig	Pli, Mio Olig	S	Por	60				
75	Yegua	Eoc	SH	Por	150*x*	Ds	815	Crockett	3,476
76									
77	Cap rock, Mio, Olig	Pre-Ter Mio, Olig	L, S	Cav Por	*x*				
78	Mid-Olig, Jackson Cockfield, Yegua	Olig, Eoc	SH	Por	400				
79	Carrizo	Eoc	S	Por	20	DF*y*	1	Wilcox	8,180
80	Frio	Olig	S	15	10	MF	6	Vicksburg	7,717
81	Lagarto	Mio	S	Por	20	D	60	Frio	6,922

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Age, Years to End of 1937	Area Proved, Acres				Total Oil Production, Bbl.		
			Oil	Oil and Gas[a]	Gas	Total	To End of 1937	During 1936	During 1937
82	La Belle, *Jefferson*	1	20	0	0	20	2,148		2,148
83	La Blanca, *Hidalgo*	1	0	140	0	140	90,850		90,850
84	Lamar, *Aransas*	1	0	20	0	20	834		834
85	La Sal Vieja, *Willacy*	2	40	0	0	40	16,354	13,345	3,009
86	Livingston, *Polk*	5	1,698	0	0	1,698	4,274,415	1,107,898	986,851
87	Lockridge, *Brazoria*	2	700	0	0	700	283,241	4,310	278,931
88	London, *Nueces*	1	80	0	0	80	29,629		29,629
89	Lost Lake, *Chambers*	9	55	0	0	55	894,585	66,796	52,283
90	Louise, *Wharton*	4	1,570	0	0	1,570	1,744,683	531,836	612,266
91	Luby, *Nueces*	1	375	0	0	375	79,604		79,604
92	Lucas, *Live Oak*	7	0	500	4,000	4,500	205,136	22,593	36,109
93	Magnet, *Wharton*	2	340	40	40	420	131,784	2,510	129,274
94	Manvel, *Brazoria*	7	1,741	0	0	1,741	10,863,523	3,030,625	3,477,270
95	Shallow	7	748			748	[y]	[y]	[y]
96	Deep	7	993			993	[y]	[y]	[y]
97	Markham, *Matagorda*	30	300	0	0	300	6,531,305	567,389	620,292
98	Mathis, *Live Oak, San Patricio*	14	0	0	100	100			
99	Mauritz, *Jackson*	3	50	50	0	100	113,791	48,392	51,354
100	McFadden, *Victoria*	7	60	0	100	160	80,645	3,785	11,637
101	McMurray, *Bee*	1	30	0	0	30	5,550		5,550
102	McNeil, *Live Oak*	4	100	0	0	100	194,568	43,920	37,166
103	Mercedes, *Hidalgo*	3	50	0	0	50	105,235	42,715	28,338
104	Midway, *San Patricio*	1	300	0	0	300	74,602		74,602
105	Mineral, *Bee*	1	25	0	0	25	1,097		1,097
106	Moss Bluff, *Chambers, Liberty*	8	10	0	0	10	179,235	Prod. depleted 1933	
107	Mykawa, *Harris*	8	270	0	0	270	2,937,181	1,176,864	616,093
108	Nash, *Brazoria, Ft. Bend*	12	120	0	0	120	1,664,486	14,313	12,689
109	Nome, *Jefferson*	2	500	500	0	1,000	626,823	54,534	572,289
110	Normanna, *Bee*	8	70	0	10	80	55,873	3,914	6,045
111	North Dayton, *Liberty*	33	55	0	0	55	2,290,744	45,939	37,808
112	Shallow	33	25			25	800,000	0	0
113	Deep	10	30			30	1,490,744	45,939	37,808
114	North Pettus, *Bee, Goliad, Karnes*	8	950	0	50	1,000	2,625,572	556,728	784,002
115	Oakville, *Live Oak*	2	30	0	290	320	4,326		4,326
116	O'Conner McFadden, *Refugio, Victoria*	6	200	0	200+	400	421,790	93,201	80,910
117	Old Ocean, *Brazoria*	4	1,000	0	0	1,000	725,709	159,772	444,999
118	Orange, *Orange*	25	400	0	0	400	32,242,419	247,344	233,191
119	Orchard, *Ft. Bend*	12	220	0	50	270	3,276,905	206,847	179,526
120	Palacios, *Matagorda*	1	50	0	0	50	33,465		33,465
121	Pettus, *Bee*	8	600	0	100	700	8,428,157	520,961	357,975
122	Pickett Ridge, *Wharton*	3	450	0	1,000	1,450	1,433,931	675,834	709,041

TABLE 1.—(*Continued*)

Line Number	Total Oil Production, Bbl.: Daily Average during Nov. 1937	Total Gas Production, Millions Cu. Ft.: To End of 1937	Total Gas Production, Millions Cu. Ft.: During 1936	Total Gas Production, Millions Cu. Ft.: During 1937	Total Gas Production, Millions Cu. Ft.: Maximum Daily during 1937	Number of Oil and/or Gas Wells: Completed to End of 1937	Number of Oil and/or Gas Wells: During 1937: Completed	Number of Oil and/or Gas Wells: During 1937: Abandoned	Number of Oil and/or Gas Wells: At End of 1937: Temporarily Shut Down	Number of Oil and/or Gas Wells: At End of 1937: Producing Oil Only	Number of Oil and/or Gas Wells: At End of 1937: Producing Oil and Gas[b]	Number of Oil and/or Gas Wells: At End of 1937: Producing Gas Only	Number of Oil and/or Gas Wells: At End of 1937: Total Producing	Depth, Average in Feet: Bottoms of Productive Wells
82	32	165		165		1	1	0	0	1			1	8,217[7]
83	541	449		449		7	7	0	1		6		6	7,875 6,683 2,855
84	28					1	1	0	0			1	1	7,997
85	0		45			1	0	0	1	0			0	7,647
86	2,327		14			100	3	2	0	89		1	90	4,276
87	1,152	300	100	200		25	23	0	0	25			25	6,365
88	72					4	4	0	0	2	2		4	4,730 4,907[7]
89	132					13	0	0	2	8		1	9	2,735
90	1,600		1,280	1,225	38	44	5	0	2	36		2	38	5,157 6,467
91	709					19	19	0	0	19			19	4,354 5,065
92	73		2,628	3,064		40	1	y	8y	3	3	22	28	2,090[4] 3,533 5,287
93	955					19	18	0	0	18		1	19	5,562
94	8,986		825	505		164	24	1	1	158		4	162	
95	y					y	y	1	y	y		y	y	4,016
96	y					y	y	0	y	y		y	y	5,160
97	1,783					145	6	y	y	33		1	34	530 3,800
98	0					6	0	y	y	0		y	y	2,385
99	180					2	1	0	0	2			2	5,650
100	58		154y			6	2	0	1	3		2	5	2,470[4] 6,187
101	7					2	2	0	0	2			2	4,284
102	81					10	0	0	2	5		3	8	4,434 4,992
103	80		7	151		4	0	0	1	3			3	7,524
104	543					9	9	0	0	9			9	5,370 7,060
105	14					3	0	0	0	1			1	3,650
106						6	0	0	0	0			0	830[3] 5,800
107	1,393		591	741		43	2	0	y	32			32	4,593
108	14					25	0	0	y	1			1	4,300
109	1,691			398		39	31	0	0	35		4	39	6,058
110	35					8	2	0	1	5		1	6	3,630
111	92					62	0	0	4	7			7	3,800
112	0					52	0	0	0	0			0	1,200
113	92					10	0	0	4	7			7	4,800
114	1,183		554	12		95	14	1	10	76		8	84	3,664
115	3					10	4	0	4	1		5	6	2,812
116	186		3,324	3,700		13	2	0	0	4		8	12	3,100
117	2,071					7	4	0	0	7			7	8,654 9,965 10,650
118	733			216		316	1	5	14y	44			44	4,000
119	377					31	3	2	2	15			15	1,300 6,700 7,350
120	134					2	2	0	0	2			2	7,880
121	754			356		88	0	0	1	40		4	44	3,900
122	1,362		36	1,178		41	5	0	2	36		3	39	4,710

TABLE 1.—(*Continued*)

Line Number	Depth, Average in Feet	Oil Production Methods at End of 1937			Pressure, Lb. per Sq. In.[d]			Character of Oil, Approx. Average during 1937					Character of Gas, Approx. Average during 1937	
		Number of Wells				Average at End of		Gravity A.P.I. at 60° F.						
	To Top of Productive Zone	Flowing	Pumping	Gas-lift	Initial	1936	1937	Maximum	Minimum	Weighted Average	Sulphur, Per Cent	Base[e]	B.t.u. per Cu. Ft.	Gal. Gasoline per M Cu. Ft.
82		1								*y*[7]	*y*	*y*		
83	7,867 6,666 2,851							62	28	48	*y*	*y*		
84														
85	7,630				2,056	885	0	52.8	47.2	48	0.03	A		
86	4,260	59	23	7	700			39	35	38	0.05	M		
87	6,342	25			2,100*y*	2,050	e2,880	29	27	28	0.34	A		
88	4,698	1	1		750		750			25.3	*y*	*y*		
89	2,679		8		490		0	23.8	18	22.4	0.22	A		
90	5,128 6,457	29	7		730	481	248	42.1	20.2	26.3	*y*	A		
91	5,030	19			1,710		1,700			44.9	*y*	*y*		
92	2,020 3,500 5,200		3		874[4] 1,400			42	24	36	*y*	A		
93	5,551	18			*y*					25.4	*y*	A		
94		102	53	3				28	22.8	25	*y*	A		
95	3,990	33	50	3	1,500		e1,500	28	22.8	24				
96	5,000	69	3	0	2,200		e2,200	28	22.8	26				
97		9	24		*x*			27.6	23	23.2	0.21	A		
98	2,375				935									
99	5,634	2			e2,100	e2,100	e2,080	31	31	31	0.10	A		
100	2,440 6,176	3			1,185[4] 1,725					46	0.16	A	990	69
101	4,267		2		570[5]		570			47	*y*	*y*		
102		4	1		1,150					44.3	*y*	A*y*		
103		3			2,500					49.2	*y*	*y*		
104	5,323	9			1,985					34	*y*	*y*		
105			1		100		0			45	*y*	M		
106	800				280		0			29.7	0.21	A		
107		2	30		290			30.5	27	28.2	0.14	A		
108			1		800					19.9	*y*	A		
109	6,005	35			2,640	2,640		29	28	28.6	0.22	P		
110	3,613	3	2		150					40	*y*	M		
111			7					41.5	22	28	0.12	A		
112			0		*x*					24	0.12	A		
113			7		400					36	0.12	A		
114	3,655	23	53					51	45	47	*y*	M		
115	2,804	1			1,300					32	*y*	*y*		
116	3,075	1		3	365[5]	50	50	42	21	35	0.16	A	1,000	100
117	8,632	6	1		1,650					67.*y*	*y*	M		
118		1	43		*x*			27.4	20.4	23.8	18	A		
119	1,300	5	10		375			54	22	35	*y*	A		
120	7,830	2								53	*y*	*y*		
121	3,860		40		236		0	49	45	47	0.05	M		
122	4,690	33	3		900					25.2	*y*	A		

TABLE 1.—(*Continued*)

Line Number	Producing Rock						Number of Dry and/or Near-dry Holes to End of 1937	Deepest Zone Tested to End of 1937	
	Name	Age[f]	Character[g]	Porosity[h]	Net Thickness, Average in Feet	Structure[i]		Name	Depth of Hole, Ft.
82	Frio	Olig	Ss	Por	6	D	3	Frio	10,147
83	Frio	Olig	Ss	Por	20	D	4	Vicksburg	8,893
84	Frio	Olig	Ss	Por	*y*	*y*	1	Frio	9,000[4]
85	Frio	Olig	S	Por	17	Ds	1	Frio	10,286
86	Cockfield	Eoc	SH	25*x*	10	DF	33	Yegua	5,596
87	Frio	Olig	Ss	20	23	AF	12	Vicksburg	8,698
88	Catahoula	Mio	Ss	Por	8	Nf	3	Frio	7,424
89	Frio	Olig	Ss	Por	33	Ds	17	Frio	7,471[6]
90	Frio	Olig	Ss	Por	20	NF	11	Vicksburg	8,271
91	Heterostegina	Olig	Ss	Por	7	MF	1	Frio	5,337
92	Catahoula[4] Frio, Yequa	Mio, Olig Eoc	S SH	Por	28	D	22	Cook Mt.	6,789
93	Marginulina	Olig	Ss	Por	10	D	2	Frio	6,518
94					24	D	40	Vicksburg	7,957
94	Mio	Mio	SH	Por	23				
96	Marginulina	Olig	Ss	Por	26				
97	Cap rock, Pli, Mio Mid-Olig	Pre-Ter Pli, Mio Olig	L SH Ss	Cav Por	46*x*	Ds	148	Vicksburg	6,056
98	Mio	Mio	S	Por	10	ML	7	McElroy	5,526
99	Frio	Olig	Ss	Por	16	D	5	Vicksburg	7,408
100	Catahoula[4] Frio	Mio Olig	S	Por	24[4] 10	AF	9	Vicksburg	7,025
101	Yegua	Eoc	S	Por	8	NF	3	Yegua	4,379
102	Hockleyensis Cockfield	Eoc	S	Por	10	D	5	Cook Mt.	6,212
103	Frio	Olig	SH	Por	10	D	3	Frio	8,306
104	Frio	Olig	Ss	Por	15	D	1	Frio	7,003
105	Cockfield (Pettus)	Eoc	S	Por	8	NF	7	Yegua	4,252
106	Cap rock Marginulina	Pre-Ter Olig	SH	Cav Por	33	Ds	61	Vicksburg	7,375
107	Mio, Frio Heterostegina	Mio Olig	SH	Por	32	D	16	Whitsett	7,355
108	Mio, Mid-Olig	Mio Olig	S, SH	Por	60*y*	Ds	45	Vicksburg	6,800
109	Marginulina	Olig	SH	Por	10	Ds	12	Vicksburg	9,045
110	Hockleyensis	Eoc	SH	Por	17	D	6	Cook Mt.	5,038
111						Ds	109	Vicksburg	6,077
112	Pli, Mio	Pli, Mio	Ss	Por	*x*				
113	Mio, Frio Vicksburg	Mio, Olig	SH	Por	32*x*				
114	Cockfield (Pettus)	Eoc	Ss	Por	15	DF	14	Yegua	4,660
115	Cockfield (Pettus)	Eoc	Ss	Por	8	AF	5	Cook Mt.	4,502
116	Catahoula Frio	Mio Olig	SH	Por	20	DF	7	Frio	6,860
117	Frio	Olig	S	Por	22	D	6	Vicksburg	11,130
118	Pli, Mio Mid-Olig, Frio	Pli Mio, Olig	Ss, SH	Por	30*x*	D	91	Frio	7,507
119	Mio, Frio Cockfield	Mio, Olig Eoc	Ss	20*y*	30	Ds	27	Crockett	10,085
120	Frio	Olig	Ss	Por	10	D	4	Frio	8,843
121	Cockfield (Pettus)	Eoc	Ss	Por	19	DF	24	Queen City	7,569
122	Marginulina	Olig	S	Por	16	A	9	Hockleyensis	8,888

[6] In salt.

TABLE 1.—(*Continued*)

Line Numbe	Field, *County*	Age, Years to End of 1937	Area Proved, Acres				Total Oil Production, Bbl.		
			Oil	Oil and Gas[a]	Gas	Total	To End of 1937	During 1936	During 1937
123	Pierce Junction, *Harris*	17	320	0	0	320	30,883,197	1,293,178	1,302,756
124	Placedo, *Victoria*	3	3,400	0	50	3,450	4,450,332	1,347,000	2,952,157
125	Pledger, *Brazoria*	6	20	0	1,100	1,120	17,068	0	0
126	Plummer, *Bee*	2	140	0	20	160	44,763	730	44,033
127	Plymouth, *San Patricio*	3	1,970	0	0	1,970	9,103,395	3,429,482	5,015,152
128	Port Lavaca, *Calhoun*	4	200	0	30	230	344,087	133,875	63,876
129	Port Neches, *Orange*	9	175	0	0	175	4,481,779	561,260	444,580
130	Premont, *Jim Wells*	5	500	80	0	580	296,487	800	287,884
131	Raccoon Bend, *Austin*	10	2,812	0	600	3,412	19,077,575	1,941,871	2,020,909
132	Shallow	10	1,458			1,458	16,148,438	969,755	799,500
133	Deep	4	1,354			1,354	2,929,137	972,116	1,221,409
134	Ray, *Bee*	3	400	0	0	400	1,266,012	615,583	352,377
135	Refugio, *Refugio*	10	1,877	0	2,720	4,597	35,865,581	1,788,649	2,253,462
136	Shallow		1,025			1,025	22,184,935	780,000[1]	898,500[1]
137	Deep		852			852	13,680,646	1,008,649[1]	1,354,962[1]
138	Richard King, *Nueces*	1	50	0	50	100	4,737		4,737
139	Rockland, *Jasper, Tyler*	10	20	0	0	20	30,858	791	0
140	Samfordyce, *Hidalgo, Starr*	4	1,200	0	0	1,200	4,990,675	1,775,792	1,811,595
141	Sandia, *Jim Wells*	1	50	0	50	100	13,792		13,792
142	Sandy Point, *Brazoria*	1	100	0	20	120	51,584		51,584
143	Saratoga, *Hardin*	37	538	0	0	538	28,449,794	366,057	347,746
144	Satsuma, *Harris*	2	180	0	0	180	154,033	28,259	125,774
145	Saxet, *Nueces*	8	4,286	0	1,300	5,586	21,124,616	4,864,619	12,940,670
146	Schwab, *Polk*	4	0	90	0	90	105,911	34,370	42,756
147	Seabreeze, *Chambers*	2	160	0	120	280	30,064	863	29,201
148	Segno, *Polk*	2	450	0	0	450	467,433	2,140	465,293
149	Silsbee, *Hardin*	2	300	0	0	300	436,228	6,880	429,348
150	Sinton, *San Patricio*	4	225	100	0	325	72,841	11,507	7,204
151	Slick, *Goliad*	7	40	0	10	50	67,760	526	13,832
152	Sour Lake, *Hardin*	36	946	0	0	946	78,553,536	572,165	567,661
153	South Clara Driscoll, *Nueces*	1	50	0	0	50	17,214		17,214
154	South Houston, *Harris*	3	750	0	0	750	3,268,686	1,226,850	1,961,421
155	South Liberty, *Liberty*	13	344	0	0	344	15,258,277	231,740	203,675
156	Spindle Top, *Jefferson*	37	430	0	0	430	123,925,986	844,684	902,512
157	Shallow	37	280			280	51,159,400	102,500[1]	210,012[1]
158	Deep	12	150			150	72,766,586	742,184[1]	692,500[1]
159	Splendora, *Montgomery*	4	0	100	0	100	996	Abd. for oil 1935	
160	Stratton, *Nueces*	1	150	50	50	250	21,985		21,985
161	Stratton Ridge, *Brazoria*	16	25	0	0	25	12,214	Prod. depleted 1933	
162	Sugarland, *Ft. Bend*	10	1,165	0	0	1,165	26,258,210	1,732,343	1,390,959

TABLE 1.—(*Continued*)

Line Number	Total Oil Production, Bbl.	Total Gas Production, Million Cu. Ft.				Number of Oil and/or Gas Wells								Depth, Average in Feet
							During 1937		At End of 1937					
	Daily Average during Nov. 1937	To End of 1937	During 1936	During 1937	Maximum Daily during 1937	Completed to End of 1937	Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Oil and Gas[b]	Producing Gas Only	Total Producing	Bottoms of Productive Wells
123	3,045					262	14	2	8	77			77	3,800 4,800
124	8,555		137	23		168	64	*y*	*y*	163		5	168	4,773 5,995
125	0		9,550	8,051		11	1	0	0	0		11	11	6,800
126	253					10	8	0	0	9		1	10	3,042
127	15,236					147	33	0	0	147			147	5,500 5,650
128	91		134	241		13	0	1	2	7		3	10	6,251
129	1,283					20	1	0	0	19			19	3,942
130	609		23			35	29	0	1	30		4	34	2,285 3,265
131	4,294		816	633		231	12	19	13	169		2	171	
132	1,695					142	3	19	11	84		1	85	3,490
133	2,599					89	9	0	2	85		1	86	4,120
134	544					43	0	*y*	*y*	24			24	3,944
135	5,470		21,236	20,732		453*y*	32	3	13	124		65	189	2,700[4] 4,900
136	2,130[1]													3,700
137	3,340[1]													5,400
138	49		265	466		2	2	0	0	2			2	4,015
139	0					8	0	0	0	0			0	1,275
140	3,170		218	548		204	17	0	4	188		12	200	2,790
141	37		13			6	3	0	0	3		3	6	2,900[4] 4,100 5,150
142	332					6	6	0	0	6			6	6,500
143	931					757*x*	0	0	6	233			233	1,000
144	282		493			9	6	0	0	9			9	6,835
145	41,092		6,592	8,559		650	285	1*y*	36*y*	566		47	613	2,360[4] 4,090 6,760
146	89					4	1	0	1	3			3	4,877
147	576			486		7	6	1	0	3		3	6	8,190 8,455
148	1,884					27	26	0	0	27			27	5,300 6,264
149	1,508					27	25	0	0	25		2	27	6,950
150	18			455		7	0	0	6	1			1	5,530
151	14					5	1	0	3	1		1	2	4,225
152	1,407					782*x*	2	*y*	43	190			190	900
153	62					2	2	0	0	2			2	3,930
154	3,965		111	140		98	22	2	2	94			94	4,050 4,800
155	570					323	1	0	4	48			48	3,500
156	2,225					1,350	4	*y*	*y*	143			143	
157	518[1]					1,002	0			*y*			*y*	750 1,200
158	1,707[1]					348	4			*y*			*y*	2,920 5,900
159						1	0	0	1	0			0	5,840
160	151					5	5	0	0	3	1	1	5	4,725[7] 6,002 6,485
161						4	0	0	0	0			0	4,360
162	2,061					71	0	*y*	11*y*	51			51	3,600

TABLE 1.—(*Continued*)

Line Number	Depth, Average in Feet	Oil Production Methods at End of 1937			Pressure, Lb. per Sq. In.[d]			Character of Oil, Approx. Average during 1937					Character of Gas, Approx. Average during 1937	
	To Top of Productive Zone	Number of Wells			Initial	Average at End of		Gravity A.P.I. at 60° F.			Sulphur, Per Cent	Base[e]	B.t.u. per Cu. Ft.	Gal. Gasoline per M Cu. Ft.
		Flowing	Pumping	Gas-lift		1936	1937	Maximum	Minimum	Weighted Average				
123	3,780 4,780	18	59		355			41.5	21	27.6	0.17	A		
124	4,750 5,900	115	48		825 1,900					22.8 36.4	y	A		
125	6,650				2,450	2,450	2,450			55.8	y	M		
126		9			1,010	1,000								
127		145	2		2,200 1,100	2,000 1,000				32 31	y	A		
128		5	2		500	850		61	41	43	y	M	1,000	
129		4	15		155			38	19.4	29	26	A		
130	3,248	4	26							22.8	y	A		
131		70	99			x	y	38	16	30	18	A	1,000	80
132	3,280	1	83		275			32	16	28	18	A		
133	4,070	69	16		e1,800			38	32	34	18	A		
134	3,838		24		450	400	0			46	y	M		80
135		79	45		1,200			60	21	31	14	A		
136	3,600				550					33	10	A		
137	y				1,700					39	17	A		
138	4,000			2	0		0			y	y	y		
139	1,260							25	21	21	26	A		
140	2,770	138	50		1,000					21.5	y	y		
141		1	2		1,300			52	41.5		y	y		
142	6,490	6			2,200		2,025			41	y	y		
143			233		x			22	16	20	y	A		
144	6,825	9			2,400	2,400		46	41	44.5	y	M		63
145	2,340 4,080 6,720	424	127	15	1,325[4] 745	1,200 600		50	20	31	0.18	M		
146	4,855	1	2		1,400			50.7	40.4	48	y	M		
147	8,111 8,412	2	1		3,300	3,300	3,300			50	0.04	P		
148	5,150 6,261	27			700[5]	700[5]				40.4	y	M		
149	6,900	25			575[5]	575[5]			40	44	y	P		
150	5,520	1			2,200			49	36.5	47	y	A		
151	4,211		1		550	800	0			46	0.04	M		
152		12	178		x			31	16	20	y	A		
153	3,917	1	1							26	y	y		
154	3,875 4,575	71	23		1,300 1,600	1,300 1,600		32	18	25	y	A		
155		3	45		50			47	20.5	24	0.18	A		
156		9	134							26	0.24	A		
157		y	y		x			x	x	25		A		
158		y	y		400±			29	23	26		A		
159	5,835				2,000		x			65	y	M		
160	4,712 5,992 6,481	3			1,850		1,850			49.3	y	y		
161					x		x			29	x	A		
162	[3,450	42	9		e1,570	e1,376				28	0 31	A		

TABLE 1.—(*Continued*)

Line Number	Producing Rock						Number of Dry and/or Near-dry Holes to End of 1937	Deepest Zone Tested to End of 1937	
	Name	Age^f	Character^g	Porosity^h	Net Thickness, Average in Feet	Structure^i		Name	Depth of Hole, Ft.
123	Mio, Frio Vicksburg	Mio Olig	Ss	Por	130x	Ds	172	Hockleyensis	7,165
124	Heterostegina Frio	Olig	SH	Por	12	Af	9	Frio	7,242
125	Frio	Olig	S	Por	100	D	9	Frio	8,115
126	Cockfield (Pettus)	Eoc	Ss	Por	y	NF	5	Cook Mt.	4,256
127	Frio	Olig	Ss	Por	20	MC	20	Frio	7,253
128	Marginulina	Olig	S	Por	15	DF	11	Frio	6,780
129	Pli, Mio Frio	Pli Mio, Olig	SH, S	Por	40	Ds	10	Vicksburg	$7,667^6$
130	Catahoula Olig	Mio Olig	S	Por	10	D	12	McElroy	7,135
131						Df	78	Claiborne	7,061
132	Whitsett, McElroy	Eoc	Ss	25±	18				
133	Cockfield	Eoc	Ss	25±	35				
134	Cockfield (Pettus)	Eoc	SH	Por	15	DF	8	Yegua	4,253
135			SH	Por	30	D	108y	Vicksburg	9,225
136	Oakville Catahoula	Mio	SH	Por	30				
137	Frio	Olig	SH	Por	30				
138	Frio	Olig	Ss	Por	15	NF	1	Hockleyensis	7,567
139	Cockfield	Eoc	Ss	Por	10	MF	12	y	1,835
140	Frio	Olig	S	Por	20	A	38y	Hockleyensis	5,595
141	Catahoula Frio, Jackson	Mio Olig, Eoc	Ss, S	Por	7	AF	19	Hockleyensis	5,701
142	Frio	Olig	Ss	Por	7	D	2	Vicksburg	7,012
143	Lagarto Mid-Olig, Cap rock	Mio, Pli Olig, Pre-Ter	Ss, L	Por	x	Ds	217x	Salt	7,461
144	Cockfield	Eoc	S	Por	10	D	2	Yegua	7,520
145	Oakville 4 Mid-Olig Frio	Mio Olig	Ss	Por	10^4 18	DF	67	Frio	8,229
146	Cockfield	Eoc	Ss	25x	9	NF	14	Yegua	5,533
147	Frio	Olig	Ss	Por	25	Ds	4	Frio	9,647
148	Cockfield Saline Bayou	Eoc	Ss	Por	20	N	1	Cockfield	5,194
149	Cockfield	Eoc	S	Por	15±	Ds	3	Yegua	7,778
150	Frio	Olig	Ss	Por	10	D	6	Frio	7,438
151	Cockfield	Eoc	Ss	Por	10	D	9	Yegua	4,580
152	Cap rock, Pli, Mio, Mid-Olig, Jackson, Upper Saline Bayou	Pre-Ter Pli, Mio Olig, Eoc	L, Ss, SH SH	Cav Por	x	Ds	190	Yegua	7,914
153	Catahoula	Mio	Ss	Por	10	D	1	Frio	5,689
154	Mio, Frio	Mio Olig	S	Por	20 40	Ds	17	Salt	6,850
155	Mio, Mid-Olig Jackson, Yequa	Mio, Olig Eoc	SH, Ss	Por	100x	Ds	117	Upper Saline Bayou	5,174
156						Ds	126	Vicksburg	6,749
157	Cap rock Pli	Pre-Ter Pli	L, SH	Cav Por	x				
158	Mio, Mid-Olig Frio	Mio Olig	Ss	Por	69				
159	Cockfield	Eoc	Ss	Por	5	D	11	Cockfield	6,452
160	Frio	Olig	Ss	Por	12	L	1	Frio	6,904
161	Mio	Mio	S	Por	10	Ds	108	Mid-Olig	7,624
162	Heterostegina Marginulina, Frio	Olig	Ss	25±	80	Ds	6	Vicksburg	4,518

Maco Stewart Fee No. 1 came in as a Miocene producer at a total depth of 5140 feet.

Harris County.—Humble Oil and Refining Company's No. 1 Settegest was the discovery well for the Webster field. This area promises to become one of the most important on the Texas Gulf Coast. The well was dug to a total depth of 6040 ft., plugged back and completed at 6009 ft. in the Frio. The initial production was 650 bbl. through a ¼-in. choke.

Hidalgo County.—The LaBlanca field was discovered by Pantana Petroleum Company's No. 1-B Engleman. This is a major structure, but until the present time the production has been primarily gas with appreciable amounts of distillate.

Jackson County.—The Texas Company's No. 1 Mauritz opened the Ganado field. The development until the present time does not indicate a field of any great magnitude.

Jefferson County.—The Cheek field and the LaBelle field, discovered by the Magnolia Petroleum Company's No. 1 Phelan and Sun Oil Company's No. 2 Hebert-Broussard, respectively, do not at present show possibilities of developing into important producing areas.

Jim Wells County.—Magnolia Petroleum Company's No. 7 Seeligson discovered East Premont. This well was dug to a total depth of 8162 ft.,

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Age, Years to End of 1937	Area Proved, Acres				Total Oil Production, Bbl.		
			Oil	Oil and Gas[a]	Gas	Total	To End of 1937	During 1936	During 1937
163	Sullivan, *Nueces*	2	40	0	0	40	33,542	6,002	27,540
164	Taft, *San Patricio*	3	700	0	0	700	1,586,857	369,243	215,614
165	Telferner, *Victoria*	1	20	0	40	60	1,000[y]		1,000[y]
166	Thompsons, *Ft. Bend*	7	3,185	700	0	3,885	25,891,362	3,522,892	4,165,397
167	Tomball, *Harris*	5	7,350	0	1,200	8,550	8,821,407	2,626,409	3,062,072
168	Tom O'Conner, *Refugio*	4	4,400	0	0	4,400	6,656,020	1,432,159	4,572,329
169	Turtle Bay, *Chambers*	3	550	0	40	590	474,853	154,993	317,002
170	Vanderbilt, *Jackson*	4	20	0	50	70	143,264	26,809	28,435
171	Voss, *Bee*	2	100	0	0	100	67,420	36,587	30,833
172	Webster, *Harris*	1	480	0	0	480	89,431		89,431
173	Weser, *Goliad*	2	50	0	0	50	2,556	1,166	1,390
174	West Columbia, *Brazoria*	23	450	0	0	450	80,303,521	788,095	840,026
175	West Tuleta, *Bee*	6	880	25	0	905	1,543,420	349,956	231,943
176	White Point, *San Patricio*	8	0	20	3,865	3,885	96,223	5,861	17,322
177	Wilson Creek, *Matagorda*	1	50	0	0	50	24,434		24,434
178	Withers, *Wharton*	2	900	0	0	900	799,486	229,992	569,494
179	Worth, *Bee*	3	50	0	0	50	27,275	11,503	6,081
180	Total		113,858	7,995	29,750	151,603	1,216,624,938	90,865,293	120,141,429

plugged back and completed in the Vicksburg at 6595 ft. While detailed information is scarce, indications are that this well has discovered a major structure.

The Sandia field, an older gas-producing area, was opened to oil production in 1937 when Smith et al. No. 1 Wade was completed as an oil well in the Jackson at 5163 ft. This well has a total depth of 5702 feet.

Karnes County.—Oil production was discovered in the Burnell south field by Pettus Refining Company's No. 1-A Kinney, which came in as a Cockfield producer from 3653 feet.

Matagorda County.—The Palacious and Wilson Creek fields, discovered by Glenn McCarthy No. 1, Foley Land Co., and United North and South Development Company's No. 1-B Stoddard, respectively, are both producing from the Frio. The former field is producing from 7880, while the latter has a production depth of 9978 feet.

Maverick County.—The East Chittim field was discovered by Wellington Oil Company's No. 1 Chittim. This well was completed in the Edwards limestone at 3287 feet.

McMullen County.—Jones No. 4 Ezzell was the discovery well of the Ezzell field when it was completed at 1533 ft. in the Jackson. Subsequent development has indicated a large area for oil and gas production.

TABLE 1.—(*Continued*)

Line Number	Total Oil Production, Bbl.	Total Gas Production, Millions Cu. Ft.				Number of Oil and/or Gas Wells								Depth, Average in Feet
							During 1937		At End of 1937					
	Daily Average during Nov. 1937	To End of 1937	During 1936	During 1937	Maximum Daily during 1937	Completed to End of 1937	Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Oil and Gas[b]	Producing Gas Only	Total Producing	Bottoms of Productive Wells
163	159					2	1	0	0	2			2	5,780
164	2,757					69	37	1	1	67			67	4,938
165	0	63		63		1	1	0	0	1			1	5,114
166	8,979					212	4	y	y	204			204	5,290
167	7,681		140	3,567		377	74	0	0	326		51	377	5,555[4] 5,575
168	12,279					227	134	0	2	224		1	225	5,930
169	1,139			136		27	20	0	0	25		2	27	6,615
170	68					2	0	0	0	1			1	5,582
171	39					7	0	0	3	3		1	4	4,005
172	678					12	12	0	0	12			12	6,050
173	0					1	0	0	1	0			0	4,812
174	2,671					251	15	0	0	50			50	3,200 5,650
175	567		66	22		91	6	y	12y	37		7	44	3,960 4,138
176	35		1,709	2,095		45	1	0	1	0		39	39	2,375[4] 4,902
177	95					1	1	0	0	1			1	9,978
178	1,341					43	26	0	1	40		2	42	5,560
179	0					2	0	0	2	0			0	3,407
180	326,134					17,501	2,366	66	373	8,463	12	493	8,968	

Newton County.—Houston Oil Company's No. 1 Peavy Moore, drilled to a total depth of 7069 ft., plugged back and completed in the Cockfield at 6919 ft., was the discovery well for the Call field. As yet, the development of this field does not warrant a prediction as to the importance of this strike.

Nueces County.—Of the discoveries during 1937, Luby is probably the most important. This field was discovered by Seaboard Oil Company's No. 1 Luby completed in the Frio at 5050 ft. Extensions have since been completed in the Catahoula at 4088 and 4350 ft. Another field of interest is the Stratton field, which was brought in by Camp Drilling Company's No. 1 Wardner in the Frio sand at 6002 ft. after plugging back from 6484 ft. This field also has been extended by other completions at 4725 and 6486 ft. The London field was discovered by Wellington Oil Company's No. 1 Stockton, which may also prove to be of importance. The original well was drilled to a total depth of 7005 ft., plugged back and completed in the Catahoula at 4703 ft. Subsequent extensions in the Catahoula at 4761 and 4906 ft. indicate this field's possible importance. Other fields discovered during the year are Chapman, Richard King and South Clara Driscoll. Of the three, South Clara Driscoll has the greatest possibility of developing into an important producing area.

TABLE 1.—(*Continued*)

Line Number	Depth, Average in Feet	Oil Production Methods at End of 1937			Pressure, Lb. per Sq. In.[d]			Character of Oil, Approx. Average during 1937					Character of Gas, Approx. Average during 1937	
	To Top of Productive Zone	Number of Wells			Initial	Average at End of		Gravity A.P.I. at 60° F.			Sulphur, Per Cent	Base[e]	B.t.u. per Cu. Ft.	Gal. Gasoline per M Cu. Ft.
		Flowing	Pumping	Gas-lift		1936	1937	Maximum	Minimum	Weighted Average				
163	5,756	2			2,000					43	y	y		
164	3,950	64	3		600					22.4	y	y		
165	5,100	1			900		900			27.4	y	y		
166	5,100	182	22		e2,430	e2,340				25	0.20	A		
167	5,375 5,555	319	3	4	e2,490	y		45.4	37.5	41	0.04	M		80
168	5,850	224			1,040	880	880			36	0.02	A	1,000	100
169	6,600	20	5		2,400	2,400		32.6	30.6	32	y	M		
170	5,562		1		500		0			32	0.13	A		
171	4,000	1	2							45	y	M		
172	5,811	12								30	y	y		
173	4,802				750	750	0			46.5	y	y		
174		20	30					32	18	28	y	A		
175	3,935 4,102	12	18	7	792			51	45	47	y	M		
176	4,880				764[d] 2,000					31	0.09	M		
177	9,925	1								52	y	y		
178	5,545	40			800	775				26.1	y	A		
179					850					30.3	y	M		
180		5,405	3,006	52										

San Patricio County.—Schmidt No. 1, drilled by Phillips Petroleum Co., discovered the Midway field. This well produces from the Frio at 5340 ft. Further development of the field will possibly prove an area of importance.

Tyler County.—Joe's Lake was discovered by the Republic Production Company's No. 2 Hurd, which was drilled to 7641 ft. and completed in a sand of Claiborne age (Sparta).

Victoria County.—As the year neared its close, the Telferner field was brought in by W. V. Bowles' No. 1 Robertson, which was drilled to a total depth of 6120 ft., plugged back and completed at a sidetracked depth of 5114 ft. in the Frio sand. As yet, no definite information is available as to the possibilities of this area.

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TABLE 1.—(*Continued*)

Line Number	Producing Rock						Number of Dry and/or Near-dry Holes to End of 1937	Deepest Zone Tested to End of 1937	
	Name	Age[f]	Character[h]	Porosity[i]	Net Thickness, Average in Feet	Structure[j]		Name	Depth of Hole, Ft.
163	Frio	Olig	Ss	Por	10	DF	1	Frio	6,912
164	Heterostegina	Olig	Ss SH	Por	20	D	7	Frio	6,926
165	Olig	Olig	Ss	Por	8	Df	0	Frio	6,138
166	Mid-Olig, Frio	Olig	Ss	25	84	D	28	Vicksburg	8,539
167	Cockfield, Yegua	Eoc	Ss	25*x*	9	DF	36	Yegua	7,438
168	Frio	Olig	Ss	Por	45	Af	8	Frio	8,174
169	Marginulina	Olig	Ss	Por	10	D	5	Frio	8,025
170	Frio	Olig	SH	Por	8	DF	5	Frio	7,042
171	Cockfield (Pettus)	Eoc	Ss	Por	5*y*	NF	8	Upper Yegua	4,308
172	Marginulina-Frio	Olig	Ss	Por	40	D	3	Frio	7,777
173	Yequa	Eoc	SH	Por	7	MC	1	Yegua	5,052
174	Pli, Mio, Mid-Olig, Frio, Vicksburg	Pli, Mio Olig	Ss	Por	250±	Ds	170	Vicksburg	6,306
175	Cockfield (Pettus)	Eoc	SH	Por	11	DF	24	Mt. Selman	6,062
176	Lagarto Mid-Olig	Mio Olig	Ss	Por	10	D	27*y*	Frio	7,211
177	Frio	Olig	Ss	Por	8	Df	0	Frio	9,978
178	Marginulina	Olig	S	Por	10	Df	2	Frio	7,244
179	Cockfield (Pettus)	Eoc	SH	Por	5	D	11	Pettus	3,705
180							5,380		

TABLE 2.—*Summary of Drilling Operations on Texas Gulf Coast*

Important Wildcats Drilled in 1937

	County	Location	Total Depth, Ft.	Surface Formation	Deepest Horizon Tested
1	Aransas	Lewis Survey on Edwards Tract	9,785	Alluvium	Frio
2	Aransas	J. Orick Survey on Porterfield "D" Tract	7,226	Alluvium	Frio
3	Aransas	J. Orick Survey on McCampbell "B" Tract	7,526	Alluvium	Frio
4	Aransas	J. Orick Survey on McCampbell "A" Tract	7,856	Alluvium	Frio
5	Bee	Uranga Grant on Strauch Tract	4,277	Lissie	Yegua
6	Bee	Uranga Grant on Hicks Tract	3,674	Lagarto	Hockleyensis
7	Brazoria	C. Breen Survey on B. R. L. Co. Tract	10,424	Alluvium	Frio
8	Brazoria	C. Breen Survey on Carson Tract	10,751	Alluvium	Frio
9	Brazoria	D. Tulley Survey on Fite Tract	6,501	Alluvium	Marginulina-Frio
10	Brazoria	Geo. Tennille Survey on Phillips Tract	5,290	Alluvium	Frio
11	Brooks	Salinas Survey on Mestenas lease 2	1,931	Quaternary	Catahoula
12	Brooks	Salinas Survey on Mestenas lease 1	3,100	Quaternary	Catahoula
13	Brooks	Salinas Survey on Mestenas lease 1	3,588	Quaternary	Catahoula
14	Brooks	Salinas Survey on Mestenas lease 1	5,505	Quaternary	Vicksburg
15	Calhoun	Sisneros Survey on Marshall Tract	3,420	Beaumont	Catahoula
16	Calhoun	Sisneros Survey on Cook Tract	5,599	Beaumont	Frio
17	Calhoun	Sisneros Survey on Bennett Tract	5,752	Beaumont	Frio
18	Chambers	H. T. & B. Survey 103 on Acorn Tract	8,822	Alluvium	Frio
19	Chambers	H. T. & B. Survey 128 on White "A" Tract	8,869	Alluvium	Frio
20	Chambers	S. Barrow Survey on Lawrence "C" Tract	6,503	Beaumont	Marginulina-Frio
21	Galveston	M. Dunman Survey on Code "B" Tract	6,717	Alluvium	Frio
22	Galveston	J. Spillman Survey on M. Stewart fee	5,140	Beaumont	Miocene
23	Galveston	W. C. M. Baker Survey on J. Hughes Tract	2,712	Beaumont	Pliocene
24	Goliad	Marshall Survey on Dr. Allen Tract	4,404	Lagarto	Yegua
25	Harris	Reels & Trobrough Survey on Moody Tract	3,600	Beaumont	Miocene
26	Harris	Perry-Austin Survey on Settegast Tract	6,040	Beaumont	Frio
27	Hidalgo	Sec. 259 on Engleman "B" Tract	6,805	Beaumont	Frio
28	Hidalgo	Lat. 223 on McDougal Tract	8,077	Beaumont	Frio
29	Hidalgo	Por. 40 on Guerra Tract	3,253	Alluvium	Frio
30	Jackson	Rodriques Survey on Rodgers Tract	4,787	Beaumont	Frio
31	Jackson	Sec. 4 on Mauritz Tract	5,112	Beaumont	Frio
32	Jefferson	S. Stivers Survey on J. H. Phelan Tract	8,841	Beaumont	Frio
33	Jefferson	S. Stivers Survey on J. H. Phelan Tract	8,682	Beaumont	Frio
34	Jefferson	W. H. Smith Survey on Junker Tract	6,535	Beaumont	Frio
35	Jefferson	W. H. Burton Survey on Hebert Broussard Tract	8,216	Beaumont	Marginulina
36	Jefferson	H. Williams Survey Lange Tract	5,380	Beaumont	Oligocene
37	Jim Wells	Los Jaboncillos Grant on Seeligson Tract	8,162	Lissie	Vicksburg
38	Jim Wells	Survey 215 Bennett "A" Tract	2,261	Lissie	Catahoula
39	Jim Wells	Survey 231 on Ritter Tract	3,175	Lissie	Catahoula
40	Jim Wells	Bode Subdivision on Wade Tract	5,702	Lissie	Jackson
41	Karnes	Ballard Survey Kinney "A" Tract	3,653	Lagarto	Cockfield
42	Kleberg	K. T. & I. Subdivision on Kleberg Tract	3,952	Beaumont	Catahoula
43	Matagorda	E. Hall Survey Croker Tract	9,575	Beaumont	Frio
44	Matagorda	L. Goodwin Survey on Foley Land Co. Tract	8,682	Beaumont	Frio
45	Matagorda	B. Cotton Survey on Stoddard "B" Tract	9,978	Beaumont	Frio
46	Maverick	Block 7 on Chittim Tract	3,287	Escondido	Edwards lime
47	McMullen	Sec. 20 on Ezzell Tract	1,533	Lagarto	Jackson
48	Newton	H. T. & C. Survey No. 42 on Peavy Moore Tract	7,069	Lissie	Cockfield
49	Nueces	Sec. 38 on Chapman Tract	6,467	Beaumont	Frio
50	Nueces	Sec. 38 on Chapman Tract	5,058	Beaumont	Frio
51	Nueces	Block 6 on King Tract	6,219	Beaumont	Vicksburg
52	Nueces	Gamble Survey on Sevier "A" Tract	6,136	Beaumont	Frio
53	Nueces	Gamble Survey on Sevier Tract	5,433	Beaumont	Frio
54	Nueces	Sec. 109 on Elish Tract	4,690	Beaumont	Frio
55	Nueces	Sec. 25 on Stockton Tract	7,005	Beaumont	Frio
56	Nueces	Sec. 25 on Stockton Tract	4,906	Beaumont	Catahoula
57	Nueces	Sec. 2 on Luby Tract	5,050	Beaumont	Frio
58	Nueces	Sec. 77 on Cunningham Tract	5,306	Beaumont	Frio
59	Nueces	Sh. 9 on McCann Tract	5,099	Beaumont	Frio
60	Nueces	Sec. 125 on Dugger Tract	3,930	Beaumont	Catahoula
61	Nueces	Stratton Subdivision on Wardner Tract	6,484	Beaumont	Frio
62	Nueces	Stratton Subdivision on Wardner Tract	4,725	Beaumont	Frio
63	Nueces	Stratton Subdivision on Wardner "A" Tract	6,486	Beaumont	Frio
64	Orange	Wm. Dyson on Chesson Tract	5,946	Beaumont	Frio
65	Orange	M. E. Hall on Stark Tract	5,944	Alluvium	Frio
66	Polk	I. & G. N. Survey on Wing Tract	5,246	Lissie or Lagarto	Lower Cockfield

TABLE 2.—(*Continued*)

Important Wildcats Drilled in 1937

	Drilled by	Initial Production per Day		Choke or Bean, Fractions of an Inch	Pressure, Lb. per Sq. In.		Remarks
		Oil, U. S. Bbl.	Gas, Millions Cu. Ft.		Casing	Tubing	
1	Barnsdall	73	3	⅜	0	980	Discovery Lamar
2	Atlantic	379		3/16	1,475	1,175	Extension Aransas
3	Buckingham & Jones	86		9/64	2,825	2,500	Extension Aransas
4	Buckingham	200		⅛	2,650	2,300	Extension Aransas
5	Dirks Bros.	230		3/16	150	240	Discovery McMurray (Strauch)
6	Dougherty	40		⅛	300	140	Extension Normanna
7	Harrison & Abercrombie	280		⅛		3,750	Extension Old Ocean
8	Harrison & Abercrombie	275		⅛		3,850	Extension Old Ocean
9	H. De Arman	47		⅛	1,200	1,100	Discovery Sandy Point
10	Sterling O. & R. Co.	480	0.2	¼		600	Extension West Columbia
11	Standard of Texas	Gas	1.4				Extension Alta Mesa
12	Standard of Texas	40		Pmpg.			Extension Alta Mesa
13	Standard of Texas	350		¼	400	140	Extension Alta Mesa
14	Standard of Texas	47		3/16	100	100	Extension Alta Mesa
15	Humble O. & R. Co. and Plymouth Oil Co.	Gas					Extension Heyser (blew out; cratered)
16	Normandie	725		⅜	150	350	Extension Heyser
17	Commonwealth	200		9/64	1,090	710	Extension Heyser
18	Sun	644		¼	2,125	1,250	Extension Seabreeze
19	Sun	Dist.		¼	3,000	2,750	Extension Seabreeze
20	Salt Dome	600		¼	1,000	1,000	Extension Cotton Lake
21	Stanolind	332		¼	740	1,200	Extension High Island
22	M. Stewart	60		¼	850	600	First production Hitchcock
23	Sun	Gas			1,150	925	Extension Green's Lake
24	Dirks Bros.	30		⅜	1,750	1,750	Extension Slick
25	Stanolind	20		¼	1,350	1,200	Extension Clinton
26	Humble O. & R. Co.	650	0.25	¼	850	800	Discovery Webster (Friends-Woods)
27	Pantana	70		⅜	1,740	1,610	Discovery La Blanca (Mestenas)
28	Pantana	125		¼	3,000	3,100	Extension La Blanca
29	Fohs	131			250	150	Extension Samfordyce
30	Steinberger and Chicago Gulf	15		⅛			Extension Edna
31	The Texas Co.	65	3.1	3/16	1,925	1,850	Discovery Ganado
32	Magnolia	432		¼	2,550	2,500	Discovery Cheek
33	Magnolia	670		¼	2,030	1,850	Extension Cheek
34	Gulf	667		¼	1,075	750	Extension Fannett
35	Sun	48		¼	3,100	3,000	Discovery La Belle
36	Glen McCarthy	456		¼	700	400	Extension Amelia (W. Beaumont)
37	Magnolia	1,368		¼	1,000	2,000	Discovery East Premont
38	Graham	120		⅜	350	250	Extension Premont
39	Glasscock	260		3/16			Extension Premont
40	Smith	66		5/32	1,300	250	First production Sandia
41	Pettus	314		¼	1,040	800	Discovery Burnell South
42	Humble O. & R. Co.	90		3/16	660	225	Extension Kingsville
43	Hamman Explor. Co.	620		¼		300	Extension Hamman (S. Bay City)
44	Glen McCarthy	175		12/64	2,000	2,850	Discovery Palacious
45	United N. & S.	168		¼	2,250	2,500	Discovery Wilson Creek
46	Wellington	100		Pmpg.			Discovery East Chittim
47	Jones	186		¼	450	1,000	Discovery Ezzell
48	Houston Oil Co.	800		½	800	200	Discovery Call
49	Seaboard	125		⅛			Discovery Chapman
50	Seaboard	420		¼			Extension Chapman
51	So. Minerals	80		Jetting			Discovery Richard King
52	Wellington & Pan Am.	20		⅛	2,300	2,100	Extension Clara Driscoll
53	Wellington	78		3/16	1,300	850	Extension Clara Driscoll
54	Killam	151		5/32	1,710	1,360	Extension Clara Driscoll
55	Wellington	250		⅜	700	100	Discovery London
56	Cosner & Cosner	45		¼	1,900	1,775	Extension London
57	Seaboard	156		3/16	1,710	1,500	Discovery Luby
58	Richardson	114		¼	1,425	1,300	Extension Luby
59	Stanolind	124		⅛	800	950	Extension Luby
60	Wellington & Seaboard	168		3/16	960	480	Discovery So. Clara Driscoll
61	Camp Drlg. Co.	49		3/16	2,150	2,050	Discovery Stratton
62	Camp Drlg. Co.	40		⅛	1,750	1,700	Extension Stratton
63	Camp Drlg. Co.	120		¼	2,475	2,275	Extension Stratton
64	Tillery & Ryan	736		¼	950	950	Extension Orange
65	The Texas Co.	552	0.25	⅜	590	290	Extension Port Neches
66	Dorrance	610		¼	1,750	1,500	Extension Segno

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TABLE 2.—(*Continued*)

Important Wildcats Drilled in 1937

	County	Location	Total Depth, Ft.	Surface Formation	Deepest Horizon Tested
67	Polk	M. Victor Survey on Kirby "B" Tract	5,340	Lissie or Lagarto	Lower Cockfield
68	Polk	I. & G. N. Survey 14 on Wing Tract	6,755	Lissie or Lagarto	Saline Bayou
69	San Patricio	Sec. 81 on Schmidt Tract	5,340	Beaumont	Frio
70	Tyler	N. Hurd Survey on Hurd Tract	7,641	Beaumont	Sparta
71	Victoria	T. G. Burham Survey on D. L. Robertson Tract	6,120	Lissie	Frio
72	Wharton	T. Caladwell Survey Pierce Est. "B" lease	5,553	Beaumont	Frio

Important Wildcats Drilled in 1937

	Drilled by	Initial Production per Day		Choke or Bean, Fractions of an Inch	Pressure, Lb. per Sq. In.		Remarks
		Oil, U. S. Bbl.	Gas, Millions Cu. Ft.		Casing	Tubing	
67	Humble O. & R. Co.	480		¼	700	600	Extension Segno
68	Gulf	722		¼	1,250	1,000	Extension Segno
69	Phillips	85		5/32	2,050	1,700	Discovery Midway
70	Republic Prod. Co.	408		¼	1,100	850	Discovery Joe's Lake
71	Bowles	72		7/64	1,350	520	Discovery Telferner
72	The Texas Co.	232		13/64	850	500	First commercial production Five Corners

	In Proven Fields	Wildcats
Number of wells drilling Dec. 31, 1937	181	59
Number of oil wells completed during 1937	1,982	147
Number of gas wells completed during 1937	81	24
Number of dry holes completed during 1937	273	592

Oil and Gas Development and Production in North Texas for the Year 1937

By H. B. Fuqua* and B. E. Thompson*

(New York Meeting, February, 1938)

The area discussed herein, commonly known as the North Texas district, embraces the following 10 counties: Archer, Baylor, Clay, Cooke, Foard, Hardeman, Knox, Montague, Wichita and Wilbarger. It is underlain by two major structural features. The northernmost portion of the district, including Cooke, Montague, northern Clay, Wichita, Wilbarger, Foard and Hardeman Counties, is underlain by the system of buried mountains known as the Red River uplift, which is parallel to and closely related to the Wichita-Amarillo uplift of Oklahoma and the Texas Panhandle. While the presence of a great majority of the numerous oil fields of the area is traceable to this feature, the production

Table 1.—*Oil and Gas Production in North Texas in* 1937

Line Number	Field, *County*	Age, Years to End of 1937	Area Proved, Acres				Total Oil Production, Bbl.	
			Oil	Oil and Gas[a]	Gas	Total	To End of 1937	During 1936
1	Petrolia,[1,2] *Clay*	35	800	1,000	4,000	5,800	6,717,997	184,370
2	Worsham, *Clay*	14	300	0	0	300	236,408	0
3	K.M.A. (Deep), *Wichita-Archer*	6	20,000[3]	0	0	20,000	1,001,581	100,000±
4	All other fields, *Wichita*	26	41,000	0	0	41,000	300,715,609[6]	5,659,230
5	All other fields, *Archer*	25	23,000	0	0	23,000	108,829,002	5,336,080
6	All fields, *Wilbarger*	25	9,400	0	0	9,400	62,260,450	3,056;885
7	All fields, *Montague*	15	5,500	500	500	6,500	26,399,901	2,010,331
8	Portwood, *Baylor*	13	600	0	0	600	3,553,502	1,174,569
9	Bruhlmeyer, *Cooke*	2	600	0	0	600	1,929,526	471,863
10	Miscellaneous, *Cooke*	12	3,000	0	0	3,000	11,509,320	1,108,457
11	Thalia, *Foard*	11	0	100	0	100	271,901	25,860
12	Johnson, *Foard, Hardeman,*[4] *Knox*[5]	5	0	600	400	1,000	1,007,354	151,261
13	Total		104,200	2,200	4,900	111,300	524,432,551	19,278,906

[a] Footnotes to column heads and explanation of symbols are given on page 313.

[1] For Petrolia field total gas production was: 98,807,766 M cu. ft. to end of 1937; production for 1936 was 315,000 M cu. ft. and 286,300 M cu. ft. for 1937.

[2] Includes a few isolated producers with negligible production in other parts of county.

[3] Part of this acreage productive in shallow zones is again included in "Wichita County—all other fields" and is duplicated in total proven acreage of district.

[4] Number of dry holes drilled in county as follows: 30 to end of 1937; none during 1937. (No production.)

[5] Number of dry holes drilled in county as follows: 14 to end of 1937; none during 1937. (No production.)

[6] Previous error corrected.

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* Gulf Oil Corporation, Gulf Production Division, Fort Worth, Texas.

in Archer, southwestern Clay and southeastern Baylor Counties is due to the influence of what is known as the Cisco arch (so called because of its influence on Cisco deposition), the axis of which extends in a northwest-southeast direction across southwestern Wichita County into Archer County.

DEVELOPMENTS DURING 1937

While a number of small local productive spots were found in Wilbarger, Archer and Wichita Counties and minor local extensions made to all the producing counties in the district, only one major discovery of a deeper horizon in a previously proven area and one intensive development campaign in a horizon discovered during a previous year are of sufficient importance to justify special comment.

The Phillips Petroleum Company's No. 51 W. T. Waggoner, in the old Rock Crossing area of central Wilbarger County, was completed in a pay (3069 to 3071 ft.) of lower Canyon age for an initial production of 276 bbl. in 3 hr. This pay is lower stratigraphically than any previously found in the county and considerable development both by drilling of new wells and by deepening of old depleted producers has followed.

The intensive development of what is known as the K. M. A. (deep) pay in southwestern Wichita County during the latter part of the year 1937 far exceeds in importance any other activity in the North Texas district. The discovery well in this deeper horizon was drilled by the Deep Oil Development Co. on S. I. and H. M. Munger land, and was completed on July 23, 1931, in sand and lime pay at a depth of 3977 ft. for an initial production of 140 bbl. Development of this pay progressed very slowly, only 11 wells having been completed to Jan. 1, 1937. Dur-

TABLE 1.—(*Continued*)

Line Number	Total Oil Production, Bbl.		Number of Oil and/or Gas Wells						Depth, Average in Feet, to Top of Productive Zone	Oil Production Methods at End of 1937	
	During 1937	Daily Average during Nov. 1937	Completed to End of 1937	During 1937		At End of 1937				Number of Wells	
				Completed	Abandoned	Producing Oil Only	Producing Gas Only	Total Producing		Flowing	Pumping
1	208,443	590	649	24	0	449	45±	494	1,500	0	449
2	30,408	163	8	4	0	4	0	4	3,800	4	0
3	659,123	3,597	102	91	0	102	0	102	3,800	88	14
4	5,856,253	15,613	11,222	174	151	6,565	0	6,565	1,500	0	6,565
5	4,634,381	11,877	6,549	141	230	3,876	0	3,876	1,300	0	3,876
6	3,198,429	8,788	1,947	56	0	1,364	0	1,364	1,700	10±	1,354
7	2,211,102	6,279	991	96	35	860	21	881	1,000	0	860
8	642,202	1,533	185	2	1	165	0	165	1,400	0	165
9	1,457,663	3,277	127	24	0	127	0	127	2,000	0	127
10	1,225,621	3,422	709	103	42	643	0	643	1,200	0	643
11	22,043	244	13	0	1	7	4	11	2,000	0	7
12	243,097	506	10	3	0	7	3	10	3,800	7	0
13	20,388,765		22,512	718	460	14,169	73	14,242		109	14,060

ing that year, 91 wells were completed, making a total of 102 wells in the field as of the first of this year. Of this number only 14 are pumping and only 8 in the field are incapable of making the approximately 55 bbl. per day which they are allowed under the proration schedule now in effect. The oil is normal North Texas Pennsylvanian crude of approximately 42° gravity and low sulphur content. Reported initial productions range from 25 to 6000 bbl. daily. Development and structural information indicates that not less than 20,000 acres will be productive in this horizon.

The producing section in this field may be briefly described as a sand, sandy lime, and lime section, the limestone in part being very oolitic. Thin shale partings are common in the section. The producing zone has been placed in the Middle Strawn formation of Pennsylvanian age. The average thickness of the pay section varies considerably in different parts of the producing area, as does the sand, shale and limestone content of the various beds. However, information obtained from samples and cores indicates that the saturated section will average about 100 ft. It appears at this time that the west and southwest parts of the field, where the section is predominantly sandstone, will yield ultimate recoveries considerably in excess of the north and east parts, where a greater percentage of limestone is present.

General Comments

Acid treatment of wells, which has played an important part in the development of certain limestone areas of the district, was greatly reduced during 1937. It is used to a limited extent in parts of Wilbarger County and in the K. M. A. area mentioned above, although in the latter area the use of nitroglycerin apparently gives better results.

TABLE 1.—(*Continued*)

Line Number	Character of Oil, Approx. Average during 1937					Producing Rock					Deepest Zone Tested to End of 1937	
	Gravity A.P.I. at 60° F.			Sulphur, Per Cent	Base[e]	Name	Age[f]	Character[g]	Net Thickness, Average in Feet	Structure[i]	Name	Depth of Hole, Ft.
	Maximum	Minimum	Weighted Average									
1	y	y	36.0	0.15	P	Numerous	Per, Pen	S	10±	A	Cam-Ord	4,289
2	y	y	38.0	y	P	Worsham Pay	Pen	LS	40±	D	Pen (Bend)	5,127
3	44.0	42.0	43.0	y	P	K.M.A. (deep)	Pen	LS	100±	AM	Cam-Ord	5,430
4	41.8	36.1	39.0	0.30	P	Numerous	Per, Pen	SL	20±	AM	Pre-Cam	3,502
5	40.2	36.8	38.5	0.38	P	Numerous	Pen	SL	10±	ML	Cam-Ord	5,750
6	38.5	35.5	37.0	0.65	P	Numerous	Per, Pen	SL	20±	AD	Pre-Cam	3,007
7	34.0	24.1	29.0	0.90	P	Numerous	Pen	SL	20±	AD	Pre-Cam	2,915
8	37.0	37.0	37.0	0.38	P	Swastika sand	Pen	S	10±	ML	Pen (Strawn)	4,265
9	42.0	39.0	41.0	x	P	Bruhlmeyer sand	Pen	S	15	NL	Pen	2,500
10	41.0	23.5	35.0	0.65	P	Several	Pen, Ord	SL	10±	AD	Pre-Cam	3,790
11	y	y	39.0	0.20	P	Thalia sand	Pen	SL	22±	D	Pre-Cam	2,550
12	45.0	40.8	43.0	0.30	P	Johnson lime	Pen	LS	30±	AF	Pre-Cam	5,003
13												

Since most of the wells outside of the K. M. A. district in Wichita County are submarginal, the effect of proration is negligible.

OUTLOOK FOR 1938

In 1937, the production of the district increased by about 1,100,000 bbl. over 1936. Principal increases were in the Bruhlmeyer pool, Cooke County, and in the K. M. A. (deep) area of Wichita County. Principal decreases were in Archer and Baylor Counties. In Archer County the number of abandonments exceeded the number of new completions.

During the year 1938 an intensive drilling campaign, probably of the magnitude of 700 wells, is expected in the K. M. A. district, with routine development in the other producing counties, and production of the district as a whole will in all probability again show an increase over the preceding year.

TABLE 2.—*Summary of Drilling Operations in North Texas*

Important Wildcats Drilled in 1937

	County	Location			Total Depth, Ft.	Surface formation	Deepest Horizon Tested	Drilled by	Initial Production per Day	Choke or Bean, Fractions of Inch	Pressure, Lb. per Square Inch		Remarks
		Fee	Survey	Sec.-Blk.					Oil, U. S. Bbl.		Casing	Tubing	
1	Wilbarger	Waggoner	H. & T. C	44-4	3,071	Permian	Pennsylvanian	Phillips Petr. Co.	276—3 hr.	Open	7	2	See text
2	Clay	Worsham	H. & T. C.	38-4	3,927	Permian	Pennsylvanian	Walter H. Gant	2,000	Open	7	2	Old Pool—Deeper Horizon
3	Wichita	Mangold	Castleman	Abst. 35	3,752	Permian	Pennsylvanian	Kadane et al.	4,172	Open	7	2	Important Extension K.M.A.

Oil and Gas in North Central Texas in 1937

By H. W. Imholz*

Considerable stimulation was given to the interest in the lower producing zones of the North Central Texas area when several wildcat wells developed production in these formations.

The Iron Mountain and Humble-Olander well in sec. 196, B.B.B. and C. survey, Jones County, Texas, had a potential of 7500 bbl. (after a 3000-gal. acid treatment) from the Palo Pinto (?) limestone encountered from 3238 to 3250 ft. This well heightened the prospects for oil in commercial quantities in the Canyon, Strawn, Bend and Ellenburger formations in the adjoining counties of Shackelford, Haskell, Throckmorton and others.

The Hickok-Van Parmer well in sec. 477 S.P.R.R. Co. survey, Eastland County, Texas, was good for 1040 bbl., natural, from the Ellenburger limestone, encountered from 4024 to 4033 feet.

The Hal Hughes-Cook and Jordan (Poindexter) well in sec. 350, block 6, S.P.R.R. Co. survey, Callahan County, flowed 890 bbl. in 9 hr., after acid treatment, from the Ellenburger limestone, encountered from 4369 to 4388 feet.

Both of the Ellenburger wells apparently are maintaining the pressure and volume of their original potential tests, and will no doubt open up considerable area in the adjoining counties for prospecting to the Ellenburger limestone.

Production increased in the district from 12,081,871 bbl. in 1936 to 15,384,500 bbl. The increase was due to developments in Jones and Jack Counties. Jack County production increased from 896,680 bbl. in 1936 to 3,117,063 in 1937, while Jones County increased from 1,596,743 bbl. in 1936 to 2,289,322 in 1937. The remaining counties of the district showed a slight decrease in the amount of oil produced.

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* Consulting Geologist, Abilene, Texas.

TABLE 1.—*Oil and Gas Production in North Central Texas in* 1937

Line Number	Field, *County*	Age, Years to End of 1937	Area Proved, Acres	Total Oil Production, Bbl.			
			Oil	To End of 1937	During 1936	During 1937	Daily Average during Dec. 1937
1	Bull-Alcorn, *Brown*	10	100	122,261	4,159	4,864	12
2	Byler, *Brown*	11	290	824,342	18,939	12,123	29
3	Byrd Store, *Brown*	17	250	391,301	7,141	4,093	10
4	Childress, *Brown*	10	180	781,985	35,322	49,454	125
5	Clark-Buffalo, *Brown*	10	460	760,612	13,027	16,535	41
6	Cross-Cut, *Brown*	16	2,300	6,007,310	124,684	131,120	351
7	Fry, *Brown*	12	940	7,618,766	113,101	100,837	251
8	George, *Brown*	10	200	731,874	25,168	26,319	73
9	Smith-Ellis, *Brown*	11	450	2,204,923	46,279	48,109	137
10	Stover, *Brown*	11	1,500	6,848,119	179,448	183,979	479
11	Other fields, *Brown*		5,595	2,371,149	76,144	45,259	112
12	Total Brown County		12,265	28,662,642	643,412	622,692	1,620
13	Baum, *Callahan*	12	500	849,042	19,095	20,830	48
14	Hatchett, *Callahan*	10	375	1,283,116	89,800	79,625	188
15	Isenhour, *Callahan*	14	600	2,082,844	57,911	55,219	147
16	Moutray, *Callahan*	11	400	2,330,933	125,134	104,183	243
17	Other fields, *Callahan*		9,515	6,726,231	294,563	261,165	675
18	Total Callahan County		11,390	13,272,166	586,503	521,022	1,301
19	Burkett (Shallow), *Coleman*	13	850	2,187,186	87,863	82,657	221
20	Burkett (Deep), *Coleman*	7	200	662,060	21,462	16,323	43
21	Dibrell, *Coleman*	10	170	341,341	11,268	20,198	83
22	Eastland, *Coleman*	9	270	1,955,874	62,184	56,040	143
23	Jennings, *Coleman*	10	135	450,292	6,762	10,145	30
24	Overall, *Coleman*	11	200	1,195,623	59,967	49,664	139
25	Santa Anna, *Coleman*	15	150	433,116	10,348	31,809	81
26	Stewardson, *Coleman*	7	200	384,818	26,417	17,301	43
27	Other fields, *Coleman*		985	1,727,240	120,891	96,070	261
28	Total Coleman County		3,160	9,337,550	407,162	380,207	1,044
29	Sipe Springs, *Comanche*	18	800	1,392,012	21,452	18,436	50
30	Hillburn, *Eastland*	18	400	1,093,048	5,322	7,078	23
31	Mangum, *Eastland*	15	300	792,639	69,659	60,576	156
32	Pioneer, *Eastland*	18	1,400	5,344,095	90,809	78,248	205
33	Ramsour, *Eastland*	12	250	1,425,073	29,378	30,897	94
34	Other fields, *Eastland*		27,660	63,278,064	690,229	711,218	1,894
35	Total Eastland County		30,010	71,932,919	1,071,923	888,017	2,372
36	Desdemona, *Eastland, Erath, Comanche*	19	6,175	22,823,783	186,526	180,019	447
37	Howard, *Fisher*	3	40	130,767	73,297	46,715	80
38	Royston, *Fisher*	9	2,880	8,810,713	1,577,863	1,098,475	2,460
39	Rotan, *Fisher*	½	640	100,888		100,888	888
40	Total Fisher County		3,560	9,042,368	1,651,160	1,246,078	3,428
41	Antelope, *Jack*	5	350	y	30,701	y	y
42	Bryson, *Jack*	5	1,000	7,224,553	808,904	3,073,966	8,385
43	Bottram, *Jack*	5	770	2,389,628	57,075	43,097	124
44	Total Jack County		2,120	9,614,181	896,680	3,117,063	8,509
45	Higgs (Sandy Ridge), *Jones*	12	450	192,860	65,858	61,175	139
46	Hawley (Dorsey-King), *Jones*	12	600	2,271,338	894,442	1,190,789	2,228
47	Leuders (Jennings), *Jones*	3	160	382,920	196,531	170,731	48
48	Noodle Creek, *Jones*	10	1,030	6,305,237	256,736	208,845	521
49	Guitar, *Jones*	1	400	388,380	5,469	382,911	1,155
50	Sayles, *Jones*	5	640	615,319	171,302	199,542	751
51	Avoca, *Jones*	½	640	41,076		41,076	308
52	Lewis, *Jones*	½	300	18,569		18,569	168
53	Other fields, *Jones*		300	87,958	6,405	15,684	51
54	Total Jones County		4,520	10,303,657	1,596,743	2,289,322	5,369
55	Moody, *Haskell*	10	40	97,562	6,098	4,829	5
56	Cook, *Shackelford*	12	1,460	14,577,636	948,377	788,409	2,075
57	Frye, *Shackelford*	12	115	305,346	8,106	8,062	39
58	Hope, *Shackelford*	14	220	1,197,249	60,124	54,627	137
59	Ibex, *Shackelford*	16	1,240	2,374,084	40,483	42,951	114
60	Bluff Creek, *Shackelford*	7	940	2,237,637	626,788	759,448	1,691
61	Newell, *Shackelford*	12	640	725,956	103,267	124,376	308
62	Petroleum Producers, *Shackelford*	8	100	129,677	12,100	10,054	155
63	Simmons-Harvey, *Shackelford*	12	160	296,220	42,331	43,064	87
64	Tannehill-Matthews, *Shackelford*	10	300	2,128,029	163,110	152,050	383
65	Other fields, *Shackelford*		7,705	9,674,693	518,841	590,759	1,531
66	Total Shackelford County		12,880	33,646,527	2,523,527	2,573,800	6,520

TABLE 1.—(*Continued*)

Line Number	Average Oil Production per Acre to End of 1937	Number of Oil Wells at End of 1937	Depth, Average in Feet		Character of Oil, Approx. Average during 1937		Producing Rock			
		Producing Oil Only	Bottoms of Productive Wells	To Top of Productive Zone	Gravity A.P.I. at 60° F.		Name	Age[f]	Character[g]	Structure[i]
					Maximum	Minimum				
1	1,223	13	1,150		40	37	Fry sand	Pen	S	ML, N
2	2,842	28	1,300		40	38	Fry sand	Pen	S	ML, N
3	1,565	8	2,450		38	37	Bend	Pen	L	A
4	4,344	62	800		38	33	Childress	Pen	S	ML, N
5	1,653	34	1,150		44	40	Fry	Pen	S	ML, N
6	2,612	206	1,200		41	39	Cross-Cut	Pen	S	ML, N
7	8,105	117	1,300		44	40	Fry	Pen	S	ML, N
8	3,659	42	1,300		40	38	Fry	Pen	S	ML, N
9	4,899	51	1,300		42	40	Fry	Pen	S	ML, N
10	4,565	203	1,200		42	40	Blake	Pen	S	ML, N
11		302								
12		1,064								
13	1,698	36	1,700		40	38	Cross Plains	Pen	S	ML, N
14	3,421	98	400		39	38	Moutray	Pen	S	ML
15	3,471	143	700		38	36	Isenhour	Pen	S	ML
16	5,662	114	750		39	36	Moutray	Pen	S	ML
17		960								
18		1,351								
19	25.73	180	400		35	34	Burkett	Pen	S	ML
20	3,310	34	1,550		43	40	Cross-Cut	Pen	S	ML, N
21	2,007	11	1,900		44	40	Gwinnup	Pen	S	ML, N
22	7,244	31	2,000		43	41	Gwinnup	Pen	S	ML, N
23	3,336	25	1,150		40	38	Fry	Pen	S	ML, N
24	5,978	24	2,300		44	40	Strawn	Pen	S	A
25	2,887	8	1,500		40	38	Fry	Pen	S	ML, N
26	1,924	25	1,450		40	38	Fry	Pen	S	ML, N
27	1,753	59								
28		397								
29	1,740	85	300		37	34	Strawn	Pen	S	A
30	2,732	2	3,100		39	35	Bend	Pen	L	MN
31	2,649	46	1,200		42	33	Strawn	Pen	S	N
32	3,817	58	2,450		42	40	Caddo	Pen	L	AF
33	5,700	9	3,600		40	38	Bend	Pen	S	N
34	2,287	393								
35		508								
36	3,696	96		2,750	44	34	Desdemona	Pen	S	A
37	3,269	2		3,670	37	35	*y*	Pen	L	A
38	3,059	112		3,100	41	38	Saddle Creek	Pen	L	A
39	158	21		3,500	40	37	Camp Colorado	Pen	L	MN
40		135								
41	*y*	*y*		600						
42	7,224	486		4,800	40	38	Strawn	Pen	S	N
43	2,103	26		26	40	38	Strawn	Pen	S, L	N
44	9,327	611								
45	428	19		1,900	38	37	Bluff Creek sand	Pen	S	N
46	1,491	101		1,900–2,300	42	37	7 Cisco sands		S, L	A
47	2,393	18		2,040	40	37	King	Pen	S	A
48	6,121	91		2,500	39	38	Camp Colorado	Pen	L	MC, A
49	971	64		2,000	38	37	Cook Horizon	Pen	L	A
50	961	28		1,950	41	40	Cook sand	Pen	S	A
51	64	8		3,200	40	38	Strawn-Canyon	Pen	L	A
52	57	5		1,900	40	38	Bluff Creek	Pen	S	ML, N
53										
54										
55	2,439	6		1,800	37	36	King	Pen	S	N
56	9,985	228		1,300	38	36	Cook sand	Pen	S	ML, N
57	2,655	51		450	36	34	Frye sand	Pen	S	ML, N
58	5,442	52		1,500	38	36	Hope sand	Pen	S	ML, N
59	1,914	19		3,500	40	38	Caddo limestone	Pen	L	N
60	2,380	197		1,600	39	38	Petroleum Producers sand	Pen	S	ML, N
61	1,134	109		1,100	38	36	Tannehill sand	Pen	S	ML, N
62	1,296	13		1,650	40	38	Petroleum Producers sand	Pen	S	N
63	1,851	12		1,700	40	38	Petroleum Producers sand	Pen	S	N
64	7,093	90		1,150	39	37	Tannehill sand	Pen	S	ML, N
65	1,256	952								
66	35,006	1,723								

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Age, Years to End of 1937	Area Proved, Acres	Total Oil Production, Bbl.			
			Oil	To End of 1937	During 1936	During 1937	Daily Average during Dec. 1937
67	Curry, *Stephens*	17	2,580	9,325,197	87,900	101,052	327
68	Strawn, *Stephens*	20	850	4,421,646	96,230	86,691	239
69	Other fields, *Stephens*		44,570	109,972,995	1,461,634	1,289,968	3,491
70	Total Stephens County		48,000	123,719,838	1,645,764	1,477,711	4,057
71	Miscellaneous, *Taylor*		170	240,674	28,946	23,630	75
72	Woodson (Deep), *Throckmorton*	13	260	1,743,536	64,770	48,823	124
73	Woodson (Shallow), *Throckmorton*	12	120	695,765	39,973	31,424	79
74	Other fields, *Throckmorton*		720	631,558	59,319	65,620	154
75	Total Throckmorton County		1,100	3,070,859	164,062	145,867	357
76	Bunger, *Young* S/2	16	1,040	3,724,124	66,072	63,529	161
77	Graham, *Young*	11	380	1,683,347	36,666	34,023	58
78	Graham-Vic, *Young*	7	320	488,000	154,421	128,670	329
79	Herron City, *Young*	16	500	1,565,172	13,716	11,873	89
80	Kisinger, *Young*	8	410	2,394,589	156,915	115,935	328
81	So. Bend, *Young*	20	1,440	10,161,372	142,011	141,053	318
82	Rathke, *Young*		y	y,684,308	y,332,844	351,464	493
83	Other fields, *Young*		13,349	33,509,162	619,708	1,049,260	3,513
84	Total Young County		17,439	55,210,079	1,522,353	1,895,807	5,289
85	Total for North Central Texas		153,629	392,366,817	12,105,394	15,384,500	

Line Number	Average Oil Production per Acre to End of 1937	Number of Oil Wells at End of 1937	Depth, Average in Feet		Character of Oil, Approx. Average during 1937		Producing Rock			
					Gravity A.P.I. at 60° F.					
		Producing Oil Only	Bottoms of Productive Wells	To Top of Productive Zone	Maximum	Minimum	Name	Age[f]	Character[g]	Structure[i]
67	3,614	51		3,100	39	38	Caddo limestone	Pen	L	A
68	5,202	98		1,850	39	37	Strawn	Pen	S	ML, N
69	2,467	582								
70	11,383	731								
71	1,417	14								
72	6,705	10		3,900	39	37	Caddo limestone	Pen	L	A
73	5,798	10		2,350	38	36	Strawn sand	Pen	S	ML
74		132								
75		152								
76	3,580	44		2,600	38	36	Strawn		S	A
77	4,429	10		3,900	39	37	Bend-Strawn		S, L	A
78	1,525	21		2,750	39	37	Strawn sand		S	A
79	3,130	12		2,600	38	36	Strawn sand		S	ML, N
80	5,840	40		2,500	40	38	Strawn sand		S	A
81	7,056	76		4,000	41	39	Strawn-Bend		S	ML, N
82		26								
83		96								
84		325								
85										

Oil and Gas Development in the Texas Panhandle for the Year 1937

By Henry Rogatz*

(New York Meeting, February, 1938)

During the year 1937, there were 663 oil wells drilled in the Texas Panhandle, making a daily initial production of 322,332 bbl.—that is, 191 more oil wells drilled than in the previous year, with an increase in the total daily initial production of 66,283 bbl. The total daily potential of the field as determined by the Texas Railroad Commission in its Schedule of Dec. 17, 1937, was 1,039,982 bbl., or an increase of 205,094 bbl. over the previous year. On Dec. 17, 1937, the daily allowable of 68,578 bbl. was assigned to the entire field. The total amount

Table 1.—*Oil and Gas Production in Texas Panhandle*

Line Number	County	Age, Years to End of 1936	Area Proved, Acres			Total Oil Production, Bbl.			
			Oil	Gas	Total	To End of 1937	During 1936	During 1937	Daily Average during Nov. 1937
1	*Carson*	16	14,810	220,383	235,193	27,591,843	1,942,154	2,561,282	6,854
2	*Gray*	12	45,960	119,815	165,775	137,188,498	10,902,391	13,338,798	34,785
3	*Hartley*	9		39,380	39,380				
4	*Hutchinson*	15	49,420	171,244	220,664	121,283,431	5,488,049	7,437,401	20,927
5	*Moore*	11	680	404,736	405,416	3,844,029	494,925	495,607	1,361
6	*Potter*	18		110,349	110,349				
7	*Wheeler*	12	7,180	121,299	128,479	14,272,854	3,644,008	3,884,263	7,353
	Total		118,050	1,187,206	1,305,256	304,180,655	22,471,527	27,717,351	71,280

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* Consulting Geologist, Amarillo, Texas.

of oil produced for the year was 27,717,351 bbl.—a daily average of 71,280 bbl. Up to Jan. 1, 1938 the total production of oil was 304,180,655 bbl. The total proven productive area includes 118,050 acres; the equivalent of 184 square miles.

During the last year, there has been a small amount of experimentation in acidizing of oil wells. To the present time, there has been too little work accomplished to state its true value, although, in the dolomite-producing areas, some excellent results seem assured.

There were 168 gas wells drilled during 1937, having a combined open flow of 6,310,788,000 cu. ft., which is 12 wells more than in the previous year, with an increase in the open flow of 961,988,000 cu. ft. per day. The oil wells plugged back for gas numbered 16 and have a daily open flow of 185,800,000 cu. ft. This brings the total new gas developed during the year to 6,496,588,000 cu. ft. per day. Acidization of gas wells has proved a very important part of the completion of these wells, and is responsible for much of the increased open flow this year. The daily open flow is increased from two to four times the initial volume. Sixty wells were treated, each with an average of 6450 gal., increasing the daily initial open flow an average of 22,500,000 cu. ft. per well.

TABLE 1.—(*Continued*)

Line Number	Total Gas Production, Thousands Cu. Ft.			Number of Oil and/or Gas Wells			Depth, Average in Feet		Oil Production Methods at End of 1937					Pressure, Lb. per Sq. In.[d]		
					During 1937				Number of Wells						Average at End of	
	To End of 1937	During 1936	During 1937	Completed to End of 1937	Completed	Abandoned	Bottoms of Productive Wells	To Top of Productive Zone	Flowing	Pumping	Gas-lift	Air-lift	Miscellaneous	Initial	July 1936	July 1937
1				705	99	2	3,150	3,050	y	y	y	y	y	430	354.5	335.8
2				2,100	278	6	3,100	3,000	y	y	y	y	y	430		322.8
3				4			3,200	2,900	y	y	y	y	y	430		426.8
4				2,034	316	13	3,000	2,900	y	y	y	y	y	430	282.2	306.3
5				306	100	2	3,500	3,400	y	y	y	y	y	430	401.7	394.8
6				49	3		2,500	2,300	y	y	y	y	y	430	411.8	406.1
7				701	35	10	2,550	2,450	y	y	y	y	y	430		282.5
	7,309,898,669	618,606,954	534,613,715	5,899	831											Average 350.6

[d] Footnotes to column headings and explanation of symbols are given on page 313.

Pipe-line Gas.—The pipe-line companies withdrew 235,932,335,000 cu. ft. of gas (a daily average of 646,389,000 cu. ft.). The total withdrawals by pipe-line companies increased 34,167,620,000 cu. ft. over that for 1936.

Natural Gasoline.—Throughout the year, 46 gasoline-extraction plants processed 1,464,695,000 cu. ft. per day, a total of 534,613,715,000 cu. ft. for the year. This gas yielded 273,318,108 gal. of natural gasoline. The total daily capacity of all the plants is 2,539,500,000 cubic feet.

Carbon Black.—Thirty-five carbon-black plants operated during 1937, burning 287,592,141,000 cu. ft., or a daily amount of 787,923,000 cu. ft. This produced approximately 430,000 lb. of carbon black. Four new plants, erected during 1937, increased the daily field capacity by 130,000,000 cubic feet.

Refineries.—The total runs to the eight operating refineries for the year 1937 were 13,627,469 bbl. or a daily average of 37,335 bbl., an increase of 5030 bbl. over 1936.

Storage.—The total oil in storage increased 3,151,838 bbl., from 8,009,662 to 11,161,500 barrels.

New Developments.—New developments resulting in considerable extension of the already existing pools occurred in Hutchinson, Gray and Carson Counties. There extensions augmented the known proven

TABLE 1.—(*Continued*)

	Character of Oil, Approx. Average during 1937					Character of Gas, Approx. Average during 1937		Producing Rock						Deepest Zone Tested to End of 1937	
	Gravity A.P.I. at 60° F.														
Line Number	Maximum	Minimum	Weighted Average	Sulphur Per Cent	Base[e]	B.t.u. per Cu. Ft.	Gal. Gasoline per M Cu. Ft.	Name	Age[f]	Character[g]	Porosity[h]	Net Thickness, Average in Feet	Structure[i]	Name	Depth of Hole, Ft.
1	45	32	39	0.6	M	1,094	0.43	Big Lime series (Wichita-Albany Granite Wash (Cisco?)	Per-Pen Pen	D, Da La Gw	*x*	*x*	Af	Granite Wash (Pen)	*y*
2	45	31	39	0.4	M	1,103	0.70	Big Lime series (Wichita-Albany Granite Wash (Cisco?)	Per-Pen Pen	D, Da La GW	*x*	*x*	Af	Granite Wash (Pen)	*y*
3								Big Lime series (Wichita-Albany) Granite Wash (Cisco?)	Pen	GW	*x*	*x*	Af	Granite Wash (Pen)	*y*
4	39	29	35	0.8	M	1,106	0.49	Big Lime series (Wichita-Albany Granite Wash (Cisco?)	Pen	GW	*x*	*x*	Af	Arbuckle	5,333
5	36	30	31	0.8	M	1,056	0.30	Lower Big Lime series (Wichita-Albany-Cisco)	Per-Pen	L	*x*	*x*	Af	Arbuckle	8,013
6	*y*	*y*	*y*	*y*	M	1,069		Big Lime series (Wichita-Albany) Granite Wash (Cisco?)	Per-Pen Pen	D GW	*x*	*x*	Af	Granite Wash (Pen)	*y*
7	44	30	37	0.4	M	1,070	0.28	Big Lime series (Wichita-Albany) Granite Wash (Cisco?)	Pen	GW	*x*	*x*	Af	Arbuckle	2,957

acreage in Hutchinson County by approximately 1130 acres, extending a mile northwest of the town of Stinnett; by about 3000 acres in northeast Carson County; and by about 800 acres in the Combs-Worley pool of Gray County.

Wildcats.—Ten wildcat tests were completed, none of which discovered oil. Six of these tests were completed for small gas wells ranging from three to nine million cubic feet. Five of these wells were drilled in Texas County, Oklahoma. Two important wildcat wells were commenced in 1937 and are still drilling. The I. T. I. O. Davis, in southwest Sherman County, is drilling on a magnetometer and subsurface structure. The Macon Norris is drilling in eastern Ochiltree and is below 5600 feet.

Development along Fault Zone of South Central Texas in 1937

By Joseph M. Dawson*

Although there was a very great increase in drilling activity along the fault line of south Texas during 1937 as compared with the previous three or four years, and although seven new fields were discovered, it cannot be said that any major development of importance took place. There were slightly over 550 completions during 1937, of which nearly 350 were oil wells as compared with some 275 the preceding year, of which 169 were oil wells. This increase in drilling activity was occasioned almost entirely by the greater interest in and development of Austin chalk production, principally in Caldwell, Guadalupe and Bastrop Counties. Seven fields were found, of which a brief description is given in Table 3. None has as yet assumed anything of major importance, and it is doubtful whether any will be classified as major discoveries through further development. Two were producing from the Edwards limestone, one from serpentine and the other four from the Austin chalk; the latter may be classified as extremely erratic in nature.

The major discouraging feature of the year was the rise and subsequent fall of interest and importance of Austin chalk production. Many new operators came into this district to drill and produce Austin chalk oil toward the first of the year, but in the latter months the production decline from this formation was so rapid and the production so erratic that drilling operations fell off materially and interest largely abated. This was particularly true of the Branyon field in Caldwell County, and the same statement is applicable to the Pearsall field, Frio County. The latter field, covering some 5000 acres and owned and controlled entirely by the Amerada and Rycade, had early completions from the Austin chalk as high as 22,000 bbl. per day. The decline was extremely rapid and the maintained production from 17 wells is only around 700 bbl. per day after a total recovery of less than one-half million barrels. Present estimates of recoverable oil from Chalk vary from 2000 to 5000 bbl. per acre.

A new process for the completion of producing wells from the Edwards limestone, particularly applicable to old producing areas, was developed, in that the penetration of the Edwards lime in drilled wells is now only 1 or 2 ft. as compared to between 15 and 75 ft. in wells drilled several years ago. Many new wells have been drilled in old Edwards lime producing

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* Geologist, Gulf Production Co., San Antonio, Texas.

TABLE 1.—*Oil and Gas Production in Central Texas Fault Zone*

Line Number	Field, *County*	Age, Years to End of 1937	Area Proved, Acres			
			Oil	Oil and Gas[a]	Gas	Total
1	Somerset, *Atascosa-Bexar*	25	11,390	0	0	11,390
2	Carroll, *Bostrop*	5	100	0	0	100
3	Cedar Creek, *Bostrop*	5	180	0	0	180
4	Cedar Creek-Northeast,[1] *Bostrop*	1	40	0	0	40
5	Hilbig, *Bostrop*	5	185	0	0	185
6	North Dale, *Bostrop*	5	320	0	0	320
7	Yost, *Bostrop*	9	150	0	150	150
8	Alta Vista, *Bexar*	22	300	0	300	300
9	Eckert, *Bexar*	10	850	0	0	850
10	Gas Ridge, *Bexar*	25	150	150	300	450
11	Von Ormy, *Bexar*	4	375	0	0	375
12	Yturri-Southton, *Bexar*	16	750	0	750	750
13	Branyon, *Caldwell*	7	900	0	0	900
14	Buchanan, *Caldwell*	9	250	0	0	250
15	Burdette, *Caldwell*	1	200	0	0	200
16	Danlap, *Caldwell*	7	170	0	0	170
17	Dale, *Caldwell*	10	210	0	0	210
18	Larremore, *Caldwell*	10	89	0	0	80
19	Lost Mule, *Caldwell*	1	40	0	0	40
20	Luling, *Caldwell-Guadalupe*	16	2,200	0	0	2,200
21	Lytton Springs, *Caldwell*	12	1,360	0	0	1,360
22	Salt Flat, *Caldwell*	9	1,195	0	0	1,195
23	Mebane, *Caldwell*	1	20	0	0	20
24	Chilton, *Falls*	15	40	0	0	40
25	Red Lake, *Freestone*	3½	0	*y*	*y*	*y*
26	Wortham, *Freestone-Limestone*	12	715	0	0	715
27	Frio Town, *Frio*	0	*y*	*y*	*y*	*y*
28	Pearsall-Georgetown,[2] *Frio*	4	0	0	160	160
29	Pearsall-Upper Sand,[2] *Frio*	3	400	0	0	400
30	Pearsall-Austin Chalk,[2] *Frio*	2	520	0	0	520
31	Pearsall (Combined), *Frio*	3	6,000	0	0	6,000
32	Darst Creek, *Guadalupe*	9	1,725	0	0	1,725
33	Darst Creek, Ext., *Guadalupe*	2	200	0	0	200
34	Manford, *Guadalupe*	8	30	0	0	30
35	Nash Creek, *Guadalupe*	1	25	0	0	25
36	Zoboroski, *Guadalupe*	2	375	0	0	375
37	Mexia, *Limestone*	16	3,920	0	0	3,920
38	Bains Creek, *Limestone*	13	0	0	60	60
39	Chittim, *Maverick*	1	20	0	0	20
40	South Bosque, *McLennan*	35	2,500	0	0	2,500
41	Adams, *Medina*	13	0	2,000	0	2,000
42	Chicon Lake, *Medina*	7	220	0	*y*	220
43	Ina, *Medina*	15	310	0	0	310
44	Taylor, *Medina*	13	30	0	0	30
45	Minerva-Rockdale, *Milam*	16	4,250	0	0	4,250
46	Corsicana[3] *Navarro*	41	6,710	0	0	6,710
47	Curry, *Navarro*	15	475	0	0	475
48	Richland, *Navarro*	13	440	0	0	440
49	Powell, *Navarro*	13	2,600	0	0	2,600
50	Woodbine Area, *Navarro*	12	750	0	0	750
51	Byersville, *Williamson*	4	360	0	0	360
52	Chapman	9	350	0	0	380
53	Thrall	23	475	0	0	475
54	Batesville, *Zavalla*	0	40	0	0	40
55	Cow Hill	8½	0	1,000	1,000	

[a] Footnotes to column heads and explanation of symbols are given on page 313.

[1] Also called Hantho-Nelson.

[2] Production shown combined below.

[3] Includes Mildred, Angus-Edens-Hodge, Burke, Rice-Oil Ridge.

TABLE 1.—(*Continued*)

Line Number	Total Oil Production, Bbl.				Total Gas Production, Millions Cu. Ft.				Number of Oil and/or Gas Wells							
										During 1937		At End of 1937				
	To End of 1937	During 1936	During 1937	Daily Average during Nov. 1937	To End of 1937	During 1936	During 1937	Maximum Daily during 1937	Completed to End of 1937	Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Oil and Gas^b	Producing Gas Only	Total Producing
1	10,123,236	254,315	230,651	613					1,052	0	0	0	961	0	0	961
2	78,692	16,187	32,950	134	0	0	0	0	7	2	0	0	7	0	0	7
3	216,260	16,863	21,660	45	0	0	0	0	11	0	1	0	0	0	0	10
4	e1,500	0	e1,500	10	0	0	0	0	1	1	0	1	0	0	0	1
5	1,261,665	259,453	203,800	410	0	0	0	0	18	0	0	0	12	0	0	12
6	494,034	73,366	59,138	140	0	0	0	0	25	5	4	0	17	0	0	17
7	870,533	11,552	13,622	25	0	0	0	0	25	0	0	0	8	0	0	8
8	105,901	1,719	1,702	5	0	0	0	0	41	0	7	0	34	0	0	34
9	807,594	85,215	63,365	157	*x*	*x*	*x*	*x*	136	0	9	0	118	0	0	118
10	62,573	1,030	1,894	7	1,320	114	112	0.3	120	0	0	0	13	0	66	79
11	105,831	40,156	49,775	143	0	0	0	0	86	13	0	0	67	0	0	67
12	603,851	21,534	21,185	51	0	0	0	0	138	0	0	0	106	0	0	106
13	841,109	56,782	700,071	1,873	0	0	0	0	161	138	0	0	161	0	0	161
14	251,642	12,864	69,504	363	0	0	0	0	36	25	0	0	31	0	0	31
15	6,093	0	6,093	66	0	0	0	0	9	9	0	0	9	0	0	9
16	278,238	19,232	18,307	46	0	0	0	0	18	5	3	0	11	0	0	11
17	1,384,335	83,346	50,441	133	0	0	0	0	57	11	12	0	40	0	0	40
18	268,505	16,647	23,168	96	0	0	0	0	18	5	0	0	12	0	0	12
19	e800	0	e800	e10	0	0	0	0	1	1	0	0	1	0	0	1
20	67,605,292	2,093,993	2,321,160	7,032	0	0	0	0	613	14	8	0	537	0	0	537
21	8,164,188	130,736	118,788	319	0	0	0	0	359	0	12	0	160	0	0	160
22	36,695,159	1,467,129	1,618,861	4,400	0	0	0	0	376	17	2	0	234	0	0	234
23	*y*	*y*	*y*	*y*	0	0	0	0	1	1	0	0	1	0	0	1
24	92,630*y*	1,560	*y*	*y*	0	0	0	0	3	0	0	0	0	0	0	0
25	0	0	0	0	*y*	487	*y*	*y*	3	0	0	0	0	0	3	3
26	22,494,057	30,327	32,130	*y*	0	0	0	0	322	0	0	0	7	0	0	7
27	*y*	*y*	*y*	*y*	*x*	*x*	*x*	*x*	1	1	0	0	1	0	0	1
28					106	*y*	*y*	*y*	1	0	0	0	0	0	1	1
29					0	0	0	0	4	0	0	0	0	0	0	4
30					0	0	0	0	14	1	0	0	14	0	0	14
31	620,904	334,228	262,177	515	106	*y*	*y*	0	18	1	1	0	16	0	0	16
32	41,267,621	3,266,651	2,635,452	7,244	0	0	0	0	289	7	0	0	273	0	0	273
33	243,677	131,449	112,228	184	0	0	0	0	34	23	11	0	23	0	0	23
34	380,568	11,454	9,184	21	0	0	0	0	4	0	3	0	1	0	0	1
35	14.285	0	14,285	156	0	0	0	0	1	1	0	0	1	0	0	1
36	128,138	41,285	82,353	160	0	0	0	0	30	7	0	0	16	0	0	16
37	95,392,747	765,789	703,245	2,000±	0	0	0	0	552	2	*y*	*y*	264	0	0	264
38	0	0	0	0	*y*	3	*y*	*y*	5	0	0	0	0	0	5	5
39	*y*	*y*	*y*	*y*	0	0	0	0	1	1	0	0	1	0	0	1
40	93,361	4,380	4,531	*y*	0	0	0		123	0	0	0	30±	0	0	30±
41	0	0	0	0	12,071	302	300*y*	1.0	46	0	*y*	*y*	*y*	0	*y*	*y*
42	28,910	5,627	6,821	19	*y*	*y*	*y*	*y*	28	0	1	0	21	*y*	6	21
43	150,697	3,393	2,538	6	0	0	0	0	31	0	0	0	12	0	12	12
44	31,935	1,628	2,933	5	0	0	0	0	6	4	3	0	3	0	0	3
45	3,382,524	78,792	71,963	188	0	0	0	0	574	0	24	0	419	0	0	419
46	13,756,554	166,750	159,489	*y*	0	0	0	0	2,937*y*	0	0	*y*	*y*	*y*	*y*	634±
47	6,752,613	44,154	43,869	*y*	0	0	0	0	54	0	*y*	*y*	12	0	0	12
48	6,619,080	6,795	6,240	16	0	0	0	0	107±	0	0	0	2	0	0	2
49	108,510,790	804,989	790,522	2,350±	0	0	0	0	741±	*y*	*y*	*y*	169	0	0	169
50	*y*	11,868	*y*	*y*	*y*	*y*	*y*	*y*	247±	*y*	*y*	*y*	*y*	*y*	*y*	*y*
51	431,076	118,786	73,176	86	0	0	0	0	44	10	4	0	40	0	0	40
52	4,069,685	118,944	100,352	210	0	0	0	0	114	0	1	*y*	73	*y*	*y*	73
53	2,406,307	18,615	16,810	44	*y*	0	0	0	200±	0	0	0	18	0	0	18
54	9,841	0	9,841	0	0	0	0	0	1	1	1	0	0	0	0	0
55	0	0	0	0	*x*	*x*	*x*	*x*	7	0	0	0	0	0	7	7

TABLE 1.—(*Continued*)

Line Number	Depth, Average in Feet		Oil Production Methods at End of 1936						Pressure, Lb. per Sq. In.[d]			Character of Oil, Approx. Average during 1936				
			Number of Wells							Average at End of		Gravity A.P.I. at 60° F.				
	Bottoms of Productive Wells	To Top of Productive Zone	Flowing	Pumping	Gas-lift	Air-lift	Misc.	Injection into Reservoir[c]	Initial	1936	1937	Maximum	Minimum	Weighted Average	Sulphur, Per Cent	Base[e]
1	2,100	1,200	0	961	0	0	0	0	300	0	0	39	34	36	1.4	P
2	2,378	2,300	0	7	0	0	0	0	0	0	0	36	36	36	0.0	P
3	1,700	1,650	0	10	0	0	0	0	100	0	0	36	34	35	0.2	P
4	1,950*y*	1,925	0	1	0	0	0	0	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*
5	2,575	2,450	11	1	0	0	0	1	1,240	*y*	680	37	37	37	0.2	P
6	2,160	2,025	0	17	0	0	0	0	150	0	0	38	36	37	0.3	P
7	1,500	1,335	0	8	0	0	0	0	400	*y*	0	28	26	27	0.3	P
8	250	220	0	34	0	0	0	0	*y*	0	0	36	34	35	0.3	P
9	790	620	0	118	0	0	0	0	*x*	*x*	*x*	35	33	34	0.3	P
10	760	230	0	13	0	0	0	0	*x*	*x*	*x*	23	21	22	0.4	P
11	730	506	0	67	0	0	0	0	*y*	0	0	34	34	34	0.4	P
12	800	600	0	106	0	0	0	0	0	0	0	33	31	32	0.5	P
13	2,275	1,816	0	161	0	0	0	0	*y*	*y*	*y*	38	36	37	0.8	P
14	2,075	1,750	0	31	0	0	0	0	*y*	*y*	*y*	37	35	36	0.2	P
15	2,235	2,210	0	9	0	0	0	0	200	0	0	33	31	32	0.8	P
16	2,275	2,300	0	11	0	0	0	0	400	0	0	37	35	36	0.6	P
17	2,250	1,915	0	40	0	0	0	0	150	0	0	38	36	37	0.2	P
18	1,315	1,285	0	12	0	0	0	0	0	0	0	23	23	23	0.6	M
19	*y*	1,756	1	0	0	0	0	0	*y*	0	*y*	*y*	*y*	*y*	*y*	*y*
20	2,200	2,100	8	529	0	0	0	0	1,500	*y*	350[d]	28	26	27	0.9	M
21	1,900	1,275	0	160	0	0	0	0	1,250	0	0	39	37	38	0.4	P
22	2,740	2,670	0	234	0	0	0	0	200	0	0	36	36	36	0.6	P
23	1,771	*y*	0	1	0	0	0	0	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*
24	1,160	1,080	0	0	0	0	0	0	*x*	*x*	*x*	33	31	32	0.8	P
25	4,950	4,850	0	0	0	0	0	0	1,855	1,855	1,855		Gas Only			
26	3,050	2,990	0	7	0	0	0	0	*x*	*x*	*x*	38.6	36.2	37.3	0.2	P
27	2,606	2,606	0	1	0	0	0	0	0	0	0	*y*	*y*	*y*	*y*	*y*
28	5,850	5,750	0	0	0	0	0	0	2,100	*y*	*y*		Gas Only		0.4	
29	3,950	3,920	4	0	0	0	0	0	*y*	*y*	*y*	26	32	28	0.4	
30	5,450	5,250	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	26	32	28	0.4	
31			8	8	0	0	0	0	1,500	*y*	*y*					
32	2,700	2,650	0	273	0	0	0	0	350	0	0	37	35	36	0.8	M
33	2,450	2,375	1	22	0	0	0	0	200	0	0	34	33	33.6	0.5	M
34	2,310	2,260	0	1	0	0	0	0	1,250	0	0	37	36	37	0.9	P
35	2,585	2,570	1	0	0	0	0	0	342	0	342	27	27	27	0.8	M
36	2,200	2,050	0	16	0	0	0	0	150	g	0	30.4	30.4	30.4	0.8	P
37	3,085	3,000	0	264	0	*x*	*x*	*x*	*x*	*x*	*x*	36	34	35	0.3	P
38	2,960	2,945	0	0	0	0	0	0	875	180			Gas Only			
39	3,287	*y*	0	1	0	0	0	0	*x*	*x*	*x*	*y*	*y*	42	*y*	*y*
40	475	450	0	30±	0	0	0	0	*x*	*x*	*x*	42	40	41	0.2	P
41	1,000	900	0	0	0	0	0	0	400	100	90e		Gas Only			
42	750	260	0	0	21	0	0	0	0	0	0	21	21	21	0.1	A
43	960	940	0	12	0	0	0	0	0	0	0	19	19	19	0.7	A
44	400	290	0	3	0	0	0	0	0	0	0	18	18	18	0.4	A
45	1,700	600	0	419	0	0	0	0	*y*	0	0	40	36	38	0.2	P
46	1,260	460	0	634±	0	0	0	0	*x*	*x*	*x*	37.1	18	*x*	0.5	P
47	2,990	2,930	0	12	0	0	0	0	*x*	*x*	*x*	40	40	40	0.2	P
48	3,040	2,975	0	3	0	0	0	0	*x*	*x*	*x*	38	38	38	0.3	P
49	3,000	2,925	0	169	0	0	0	0	*x*	*x*	*x*	38	36	37	0.3	P
50	1,650	850	*y*	*y*	*y*	*y*	*y*	*y*	*x*	*x*	*x*	34.8	23.5	33.0	0.4	P
51	900	850	0	40	0	0	0	0	0	0	0	37	37	37	0.2	P
52	1,915	1,750	0	73	0	0	0	0	400	0	0	36.7	35.2	36.0	0.2	P
53	1,000	700	0	18	0	0	0	0	400	0	0	37	36	37	0.3	P
54	3,949	*y*	0	0	0	0	0	0	*y*		*y*	*y*	*y*	16	*y*	A
55	800	675	0	0	0	0	0	0	295	210	*x*		Gas			*y*

[d] On flowing wells only.

TABLE 1.—(*Continued*)

Line Number	Character of Gas, Approx. Average during 1937		Producing Rock						Number of Dry and/or Near-dry Holes to End of 1937	Deepest Zone Tested to End of 1937	
	B.t.u. per Cu. Ft.	Gal. Gasoline per M Cu. Ft.	Name	Age[f]	Character[g]	Porosity[h]	Net Thickness, Average in Feet	Structure[i]		Name	Depth of Hole, Ft.
1	*y*	*y*	Navarro sands	CreU	SH	22	30	TF	75	Travis Peak	5,311
2	1,025	2.5	Serpentine	CreU	P	12	78	Intn	3	Edwards lime	2,919
3	1,010	0.5	Serpentine	CreU	P	15–20	50	Intn	0	Edwards lime	2,300
4	*y*	*y*	Serpentine	CreU		*y*	*y*	Intn	0	Edwards lime	1,925
5	1,300	1.0	Serpentine	CreU	P	12	50	Intn	5	Edwards lime	3,250
6	*y*	1.5	Dale lime and serpentine	CreU	P	15	35	Intn	18	Edwards lime	2,950
7	*y*	1.4	Serpentine	CreU	P	15–25	100	Intn	8	Edwards lime	2,600
8	1,135	*y*	Navarro sands	CreU	S	15–20	20	F	28	Trinity sand	4,535
9	1,140	0.8	Navarro sands	CreU	S	16	10	F	16	Edwards lime	1,590
10	1,120	0.5	Navarro sands	CreU	S	15–20	15	A	39	Travis Peak	3,460
11	*y*	*y*	Navarro sands	CreU	SH	10	20	F	21	Edwards lime	2,835
12	*y*	1.8	Navarro sands	CreU	S	16	10	F	36	Glen Rose	3,850
13	*y*	1.5	Austin chalk, Edwards lime	CreU	L	Ch 15 Li 25	*y*	F	35	Edwards lime	2,450
14	*y*	1.6	Serpentine	CreU	P	12	*y*	Intn	7	Edwards lime	2,483
15	*y*	*y*	Edwards lime	CreU	L	25	25	F	5	Edwards lime	2,350
16	*y*	1.5	Austin chalk crevice	CreU	L	Crev	15	F	10	Edwards lime	2,420
17	*y*	1.5	Dale lime and serpentine	CreU	L	15	30	Intn	8	Edwards lime	2,661
18	1,120	1.3	Edwards lime	CreL	L	30	35	F	8	Glen Rose	2,150
19	*y*	*y*	Austin chalk	CreU	L	*y*	*y*	*y*	*y*	*y*	*y*
20	955	1.5	Edwards lime	CreL	L	25	100	F	85	Travis Peak schist	7,859
21	1,040	1.5	Serpentine	CreU	P	14	400	Intr	47	Edwards lime	2,292
22	Sulf	4.0	Edwards	CreL	L	30	25	F	42	Edwards lime	2,918
23	*y*	*y*	Austin chalk	CreU	L	*y*	*y*	*y*	0	Austin chalk	1,771
24	*x*	2.1	Georgetown	CreL	LS	23	5	AF	23	Glenrose	2,025
25	1,040	*y*	Woodbine sand	CreU	S	*x*	25	*x*	1	Woodbine	5,002
26	1,080	2.5	Woodbine sand	CreU	SH	25	35	F	63	Glen Rose	4,385
27	*y*	*y*	Austin chalk	CreU	Crevice		*y*	*y*	*y*		
28	*y*	*y*	Georgetown	CreL	L	*y*	59	N	0	Travis Peak	10,050
29	0	0	Navarro sand	CreU	S	20	15	N	3	Travis Peak	10,050
30	*y*	*y*	Austin chalk	CreU	C	*y*	*y*	N	2	Travis Peak	10,050
31											
32	*y*	2.3	Edwards lime	Cre	L	30	30	F	29	Travis Peak	5,509
33	*y*	1.5	Austin chalk	Cre	C	5–25	100	F		Edwards lime	3,200
34	*y*	1.5	Austin chalk	Cre	C	35	30	F	4	Edwards lime	2,800
35	*y*	1.5	Taylor	Cre	L	*y*	30	F	3	Edwards lime	3,342
36	*y*	*y*	Austin chalk	Cre	C	10	75	F	5	Edwards lime	2,600
37	1,152	2.5	Woodbine sand	CreU	SH	25	50	F	149	*y*	8,847
38	1,040	0.4	Woodbine sand	CreU	SH	20	15	F	9	Woodbine sand	3,208
39	*y*	*y*	Edwards lime	Cre	L	*y*	*y*	*y*	*y*	*y*	*y*
40	1,225	2.0	Basal Walnut	CreL	DL	22	3	AF	100	Trinity (Basal)	1,800
41	999	2.3	Escondido sand	CreU	S	*x*	20	F	12	Edwards	2,289
42	1,095	0.5	Navarro sands	CreU	SsH	15	20	Intn	0	Edwards lime	1,725
43	*y*	*y*	Navarro sands	CreU	SsH	15	15	T	34	Edwards lime	2,048
44	*y*	1.5	Navarro sands	CreU	SsH	15	15	F	17	Edwards lime	1,285
45	*y*	2.5	Navarro sands	CreU	SsH	16	15	T	46	Edwards lime	5,000
46	1,040	1.8	Corsicana Taylor Nacatoch Navarro	CreU	Ss	12–20		A AF AM	550	Woodbine sand	3,570
47	1,040	2.5	Woodbine sand	CreU	SH	22	20	F	53	Woodbine sand	3,646
48	1,060	2.5	Woodbine sand	CreU	SH	25	20	F	23	Glen Rose	5,415
49	1,080	2.5	Woodbine sand	CreU	SH	25	45	F	68	Trinity sand	6,506
50	*x*	*x*	Navarro-Taylor	CreU	Ss	14–20	15	AF	54	Trinity	6,506
51	*y*	2.0	Basal Taylor Serpentine	Cre	1	20	*y*	Intn	4	Edwards lime	2,000
52	1,025	0.8	Serpentine	Cre	1	20	75	Intn	20	Edwards lime	3,226
53	*y*	0.8	Serpentine	Cre	1	25	75	Intn	23	Travis Peak	3,290
54	*y*	*y*	Edwards	CreL	L	*y*	*y*	F	0	Edwards	3,983
55	1,015	0.2	Escondido sand	CreU	SH	*x*	20	A	10	Glen Rose	4,709

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Life	Area Proved, Acres			
			Oil	Oil and Gas[a]	Gas	Total
	Depleted Fields					
56	Chatfield,[5] *Navarro*	5 Yr.	0	0	150	150
57	Mission,[6] *Bexar*	16 Yr.	200	0	0	200
58	Witherspoon-McKis,[7] *Navarro*	20 Yr.	400	0	0	400
59	Kosse,[8] *Limestone*	8 Days	10	0	0	10
60	Nigger Creek,[9] *Limestone*	5 Yr.	170	0	0	170
61	Cedar Creek,[10] *Limestone*	4 Yr.	30	0	0	30
62	Ottine,[11] *Gonzales*	6 Mo.	10	0	0	10
63	Lytton Springs[12] (Twst), *Caldwell*	6 Yr.	50	0	0	50
64	Marlin-Satin,[13] *Falls*	3 Yr.	10	0	0	10
65	Cooksey,[14] *Bexar*	7 Yr.	50	0	0	50
66	Schimmel-Batts,[15] *Bastrop*	6 Yr.	50	0	0	50
67	Mando,[16] *Travis*	2 Yr.	40	0	0	40
68	Pearsall, Buda,[17] *Frio*	7 Mo.	40	0	0	40

[5] Discovered 1905; depleted 1910.
[6] Discovered 1912; depleted 1928.
[7] Discovered 1915; depleted 1935.
[8] Discovered 1922; depleted 1922.
[9] Discovered 1926; depleted 1931.
[10] Discovered 1927; depleted 1931.
[11] Discovered 1929; depleted 1929.
[12] Discovered 1930; depleted 1935.
[13] Discovered 1932; depleted 1935.
[14] Discovered 1929; depleted 1936.
[15] Discovered 1930; depleted 1936.
[16] Discovered 1934; depleted 1936.
[17] Discovered 1935; depleted 1936.

Line Number	Total Oil Production, Bbl.				Total Gas Production, Millions Cu. Ft.				Number of Oil and/or Gas Wells							
										During 1937		At End of 1937				
	To End of 1937	During 1936	During 1937	Daily Average during Nov. 1937	To End of 1937	During 1936	During 1937	Maximum Daily during 1937	Completed to End of 1937	Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Oil and Gas[b]	Producing Gas Only	Total Producing
56	0	0	0	0	4,750	0	0	0	15	0	0	*y*	0	0	0	0
57	63,000	0	0	0	0	0	0	0	32	0	0	*y*	0	0	0	0
58	810,495	0	0	0	0	0	0	0	85	0	0	*y*	0	0	0	0
59	33,000	0	0	0	0	0	0	0	1	0	0	*y*	0	0	0	0
60	2,998,810	0	0	0	0	0	0	0	75	0	0	*y*	0	0	0	0
61	297,945	0	0	0	0	0	0	0	14	0	0	*y*	0	0	0	0
62	12,000	0	0	0	0	0	0	0	1	0	0	*y*	0	0	0	0
63	6,273	0	0	0	0	0	0	0	3	0	0	*y*	0	0	0	0
64	1,560	0	0	0	0	0	0	0	2	0	0	*y*	0	0	0	0
65	67,228	1,686	0	0	0	0	0	0	15	0	0	*y*	0	0	0	0
66	4,301	77	0	0	0	0	0	0	6	0	0	*y*	0	0	0	0
67	15,736	4,696	0	0	0	0	0	0	2	0	0	*y*	0	0	0	0
68	20,867	4,968	0	0	0	0	0	0	1	0	0	*y*	0	0	0	0

areas with excellent results where the Edwards is penetrated only 1 or 2 ft. This has been done on abandoned producing leases where water encroachment caused the wells to be abandoned. It now appears definite that many wells will be drilled in old Edwards lime fields and oil produced through the penetration of the Edwards of only 1 or 2 ft. that would never be produced from present wells where penetration was a minimum of 20 ft. It is a skimming process, with the resultant recovery of pipe-line oil in areas heretofore considered largely water.

TABLE 1.—(*Continued*)

Line Number	Depth, Average in Feet		Oil Production Methods at End of 1936						Pressure, Lb. per Sq. In.[d]			Character of Oil, Approx. Average during 1936				
			Number of Wells							Average at End of		Gravity A.P.I. at 60° F.				
	Bottoms of Productive Wells	To Top of Productive Zone	Flowing	Pumping	Gas-lift	Air-lift	Misc.	Injection into Reservoir[c]	Initial	1936	1937	Maximum	Minimum	Weighted Average	Sulphur, Per Cent	Base[e]
56	1,020	880	0	0	0	0	0	0	250	0	0					
57	420	395	0	0	0	0	0	0	x	x	x	28	26	27	0.3	P
58	875	825	0	0	0	0	0	0	x	0	0	20	18	19	0.6	P
59	3,767	x	0	0	0	0	0	0	x	0	0	32	32	32	0.3	P
60	2,870	2,820	0	0	0	0	0	0	x	0	0	40	40	40	0.3	P
61	2,940	2,885	0	0	0	0	0	0	x	0	0	37	37	37	0.3	P
62	3,780	3,765	0	0	0	0	0	0	x	0	0	32	32	32	0.2	P
63	1,820	1,535	0	0	0	0	0	0	x	0	0	31.5	31.5	31.5	0.4	P
64	1,160	1,000	0	0	0	0	0	0	x	0	0	34.5	33.9	34.2	0.4	P
65	1,460	1,440	0	0	0	0	0	0	x	x	x	34	32	33	0.4	P
66	1,900	1,400	0	0	0	0	0	0	x	x	x	34.8	33.8	34.4	0.2	P
67	757	720	0	0	0	0	0	0	x	x	0	34	34	34	0.4	P
68	6,232	5,900	0	0	0	0	0	0	x	x		39	39	39	0.4	P

Line Number	Character of Gas, Approx. Average during 1937		Producing Rock						Number of Dry and or Near-dry Holes to End of 1937	Deepest Zone Tested to End of 1937	
	B.t.u. per Cu. Ft.	Gal. Gasoline per M Cu. Ft.	Name	Age[f]	Character[g]	Porosity[h]	Net Thickness, Average in Feet	Structure[i]		Name	Depth of Hole, Ft.
56	1,110	1.8	Taylor sand	CreU	Ss	x	13	A	7	Woodbine	3,057
57	1,120	1.3	Navarro sand	CreU	SH	18	25	F	15	Glen Rose	3,550
58	1,040	1.6	Nacatoch	CreU	Ss	14	19	AF	25	Woodbine	3,480
59	x	x	Unknown	x	x	x	x	Crev	22	Glen Rose	6,056
60	x	x	Woodbine	CreU	Ss	25	15	F	35	Woodbine	3,509
61	x	x	Woodbine	CreU	SH	25	10	F	9	Woodbine	3,310
62	x	x	Taylor sand	CreU	S	x	15	F	3	Edwards	4,281
63	x	x	Serpentine	CreU	P	12	x	Intn	12	Edwards	2,050
64	x	x	Buda-Georgetown	CreL	L	20	20	AF	8	Glen Rose	1,409
65	x	0.3	Taylor sand	CreU	S	13	10	F	7	Edwards	2,250
66	1,120	1.5	Serpentine	CreU	P	13	x	Intn	8	Austin chalk	2,001
67	x	0.4	Serpentine	CreU	P	15–25	x	Intn	3	Taylor marl	850
68	x	x	Buda limestone	CreL	L	x	x	N	0	Travis Peak	10,050

Acid treatment, particularly of the Austin chalk, is standard practice and without this method very little production could be secured from the chalk. Acid-treating is extremely important in that it will cause to be developed many producing areas in the Austin chalk, although second class in nature, that could never be produced without acid.

Not a few important wildcats have been drilled, but results were discouraging. No new major lease plays took place, except possibly in Dimmit County on the Carrizo Springs arch, and it cannot be said that the outlook at the end of the year is overly optimistic. Four tests were drilled to the Ordovician formation in the Edwards plateau, located on favorable structure, all of which were failures. Deep tests of the Glen Rose and Trinity formations in the Darst Creek field, Guadalupe County, and the Pearsall field, Frio County, were failures, and do not make deep possibilities in old fields more attractive. Table 2 gives a list of important wildcats.

TABLE 2.—*Summary of Drilling Operations in Fault Zone of South Central Texas*

Important Wildcats Drilled in 1937

	County	Location	Total Depth, Ft.	Surface Formation
1	Zavala Batesville field	Sec. 11-G W.T. and P.R.R.BL. A-2	3,947	Eocene (Bigford)
2	Caldwell (Burdette Wells)	Guadalupe College Survey	2,212	Wilcox (Eocene)
3	Guadalupe Nash Creek	John H. Burnham Survey	2,585	Wilcox (Eocene)
4	Frio Frio Town	J. Frequerros Survey No. 151	2,606	Carriso (Eocene)
5	Caldwell Lost Mule	Isaac Allen Survey No. A6.28	1,256	Wilcox (Eocene)
6	Guadalupe Davst Creek	Joel W. Robinson Survey	5,509	Wilcox (Eocene)
7	Fayette Cistern Prospect	Samuel Miller League	7,141	Crockett
8	Burleson Tanglewood Producers	Elisa Sante Survey	6,241	Sparta
9	Frio Pearsall field	San Antonio Ditch Co. Survey No. 1104	10,741	Mt. Selman
10	Real	No. 7 G. W. T. & P. R.R.	5,956	Georgetown (Cretaceous)
11	Edwards	No. 16 A. Wilkes	3,952	Edwards (Cretaceous)
12	Edwards	No. 66 J. W. Joy	5,175	Georgetown (Cretaceous)

TABLE 2.—(*Continued*)

Important Wildcats Drilled in 1937

	Deepest Horizon Tested	Drilled by	Initial Production per Day	Choke or Bean, Fractions of Inch	Pressure, Lb. per Sq. In.		Remarks
			Oil, U. S. Bbl.		Casing	Tubing	
1	Edwards LS (Cretaceous)	H. F. Wilcox O. & G. Co.	2,400	None		200	Well went to water. Abandoned. One dry offset
2	Edwards (Cretaceous)	Lanning & Coffield	40	Pump			Now four Edwards producers
3	Edwards (Cretaceous)	Duke Carver et al.	3,000	1" choke	450	225	Three dry holes Freak-Austin chalk crevice
4	Austin chalk (Cretaceous)	Pagenkopf and Jamieson	140	On swab			Crevice producer from Austin chalk
5	Edwards (Cretaceous)	McNeill Petr. Co.	70	Pump			Austin chalk crevice. Well went completely to water. One dry offset
6	Travis Peak (Cretaceous)	Diamond Half Oil Co.	Dry				Well drilled to test Trinity (Travis Peak) and Glen Rose. Went into schist at 5,480 ft. under Cretaceous
7	Edwards	Paul Teas	Show				Edwards. Showed oil. Tested water
8	Edwards	Red Bank Oil Co.	Show				Edwards. Showed oil. Tested water
9	Travis Peak	Amerada and Rycade					Tested Edwards, Glen Rose and Travis Peak formations. Several shows oil. None commercial
10	Ellenberger (Ordovician)	Sun Oil Co.	Dry Water				One of few Ordovician wells drilled
11	Ellenberger (Ordovician)	A. D. Auld	Water Dry				One of few Ordovician wells drilled
12	Ellenberger (Ordovician)	Plateau Oil & Gas Co.	Water				One of few Ordovician wells drilled Located on major anticline

TABLE 3.—*The Seven Producing Fields*

Field	County	Operator and Number of Well	Depth of Producing Formation, Ft.	Initial Production, Bbl.	Remarks
Batesville	Zavala	Wilcox, H. F. No. 1 Gillam	3,947 (Edwards)	4,410	Discovery well of field
Burdett Wells	Caldwell	Brown Drlg. Co. No. 1 Blackwell	2,198 (Edwards)	73	Discovery well
Frio Town	Frio	Pagenkopf & Jamieson No. 1 Houston Estate	TD 2,651 PD 2,606 (Austin chalk)	5	Discovery well
Lost Mule	Caldwell	McNeill Petr. Co. No. 1 Felipe Morena	1,756 (Austin chalk)	60	Discovery well
Mebane	Caldwell	Burgin, C. O. No. 1 Sarah Mebane	1,771 (Austin chalk)	5	Discovery well
Nash Creek	Guadalupe	Carver, Duke, et al. No. 1 Rumph	2,585 (Austin chalk)	496	Discovery well
NE. Cedar Creek	Bastrop	Olsen Drlg. Co. No. 1 Mrs. C. N. Murchison	1,925 (Serpentine)	100	Discovery well

Oil and Gas Development in South Texas[*] during 1937

By M. T. Halbouty,[†] Member A.I.M.E.

(New York Meeting, February, 1938)

The Laredo oil district, South Texas, includes an area of approximately 200 miles long north and south and 75 miles wide, embracing the following counties: Starr, Zapata, Jim Hogg, Webb, Duval and McMullen. The area is relatively old in respect to the production of oil, as the first oil was discovered and produced in the Piedra Pintas field in Duval County on Sept. 10, 1905. Since that date, continuous new discoveries have contributed to the development of this district until, at the present time, it is one of the important oil-producing and gas-producing areas in the world. The year 1937 also had its share of new discoveries in the district, including not only new oil fields but also new sands in already producing pools and important extensions to existing sands and fields.

Among the most important field discoveries, by counties, are:

Duval County.....	Benavides, Sweden, Thomas-Lockhart, Labbe and Lundell fields
Jim Hogg County..	Las Animas field
McMullen County.	Ezzell field
Starr County......	El Tanque field
Webb County.....	Killam and Oilton fields

Of these, Benavides, Oilton, Killam and Ezzell have so far proved themselves most important; the Benavides field, Duval County, showing by far the most activity.

For the year 1937, there were 283 wildcat tests drilled in this district, of which 35 were oil producers, 20 completed as gas wells and 228 abandoned as dry holes. Duval County, as usual, received the greatest amount of wildcat drilling, having 21 oil wells, 5 gas wells and 63 dry holes completed during the year for a total of 89 tests. Next came Webb County with 4 oil wells, 4 gas wells and 53 dry holes for a total of 61 tests.

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[*] South Texas, or Southwest Texas, as formerly it was called, is, because of its size, divided into three sections; namely, Laredo district, San Antonio district and Corpus Christi district. Since A.I.M.E. Transactions have included Corpus Christi district in Gulf Coast reports and San Antonio district in North Central Texas reports, this paper will deal only with South Texas' Laredo district. All references to South Texas, therefore, refer only to the Laredo district. Manuscript received at the office of the Institute Feb. 14, 1938.

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Following in order came Starr with 4 oil wells, 4 gas wells and 40 dry holes, total 48 tests; McMullen with 4 oil wells, 2 gas wells and 33 dry holes, total 39 tests; Zapata with 1 oil well, an extension to the Escobas field, 1 gas well and 24 dry holes, total 26 tests; and Jim Hogg County with 1 oil well, 4 gas wells and 15 dry holes for a total of 20 tests.

In South Texas, oil is produced from horizons ranging from 150 ft. in depth, as found in the Charco Redondo field in Zapata County, to 6000 ft., as found in the Sweden field of Duval County. Even though the area is mainly one of shallow production, South Texas is not to be overlooked for the possibilities from deeper horizons. With deeper producing horizons being found in South Texas, such as the Cockfield production that was discovered in the Benavides, Sweden, Thomas-Lockhart and Barbacoas fields, it is probable that the near future will see this oil picture of South Texas more changed, with the lower horizons becoming more important as a source of oil. (See Table 3.) The discovery of several new sands at deeper levels in already shallow producing fields has caused a new exploration program of the entire shallow district.

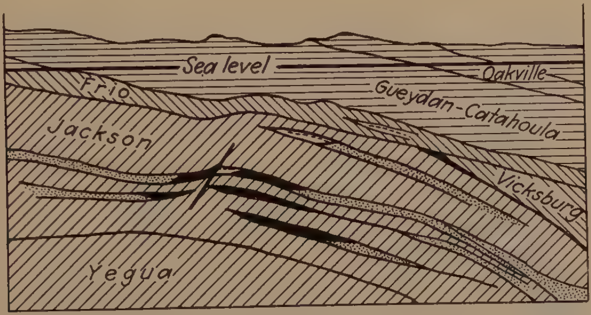

FIG. 1.—MIRANDO TYPE OF STRUCTURE, SHOWING LENSING SITUATION IN JACKSON ZONE. (*After George R. Pinkley.*)

In almost all of the localities in the district, development has been kept within certain known shallow geological zones with very little drilling projected to the lower horizons, because the shallow production, with its cheap cost of drilling and quick payout, was more alluring to the operators. However, the general possibility of deeper production throughout the entire area is so bright that South Texas can be considered as a district that has only been scratched in the search for its total oil production.

The trend in deeper drilling has been most conspicuous in wildcats. Where fairly large blocks are held, wildcats are usually drilled through several horizons, which, in turn, determine the extent of the limits of production in a new discovery. Faster drilling has also come into its own. Reduced drilling time, together with increased efficiency, has been the development in all fields. Drilling almost always is with rotary. More powerful pumps are used, together with larger hookups. Improvement in coring and testing has established many new producing levels in almost every field. South Texas has an average of at least two producing zones in every field.

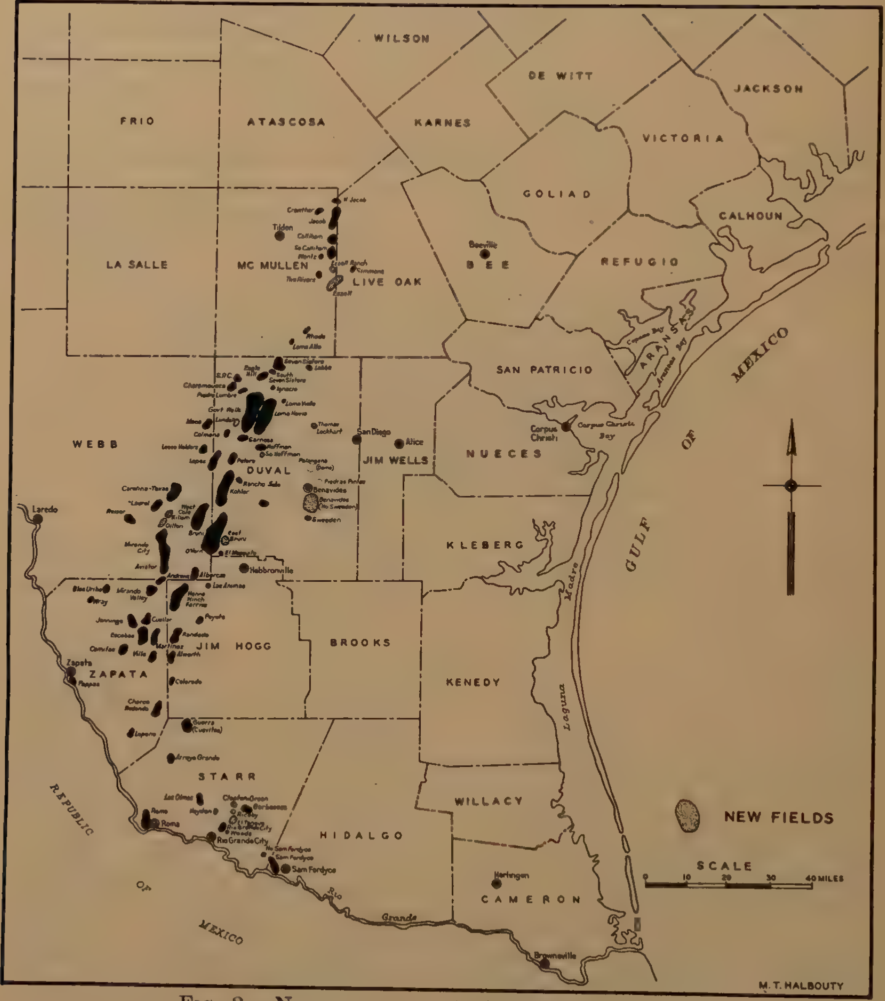

FIG. 2.—NEW FIELDS OF 1937 IN SOUTH TEXAS.

The gravity of *most* of the production in this section of Texas ranges from 19° to 26°. "Mirando type crude" is the name by which this oil is generally known, and its properties make it especially adapted to Diesel-engine operations, usually in its crude state. Besides being excellent for fuel, when refined, its lubricating qualities are ideal and its gasoline, though low in content, is of a high antiknock value. The market for this crude is thus varied. The crudes ranging up to 60° are unusually desirable for skimming. By blending gasoline made from residue gas with this high-gravity crude, a highly marketable and high-priced product is obtained.

Despite the upward trend of daily production through the years, South Texas operators have been able to discover sufficient oil to offset withdrawals, and to add considerably to its known reserves of crude oil.

Producing Formations

The accompanying stratigraphic section gives the producing formations. The Jackson formation of upper Eocene age contains the most important oil sands found in the South Texas district. It is divided into three zones: the Whitsett, sometimes referred to as the Fayette, occurs in the top of the zone; the McElroy, also commonly referred to as the Hockley, is the middle member of the zone; and the lower member is the Caddell, which also is commonly referred to as the Diboll. All three of these zones are productive in this district and carry good sections of oil sands. The Whitsett zone contains the Cole sand, which produces both oil and gas; the McElroy contains the Chernosky sand, Government Wells sand, Loma Novia sand, and upper Mirando sand, which, together, form the most prolific sand section of the entire district; and the Caddell zone contains the Low Mirando sand at its top and the O'Hern sand at its base. The three zones contain seven producing sands, or a combined producing section of 200 ft. of effective sand for the district—an average individual effective sand thickness of 22 ft. for each sand in the Jackson group. All of the sands in this group are unconsolidated and strikingly similar in lithological characteristic. The sands are fine to medium to coarse-grained, the medium grain predominating. The average characteristic shapes of these grains vary from subrounded to rounded. The sands in the Jackson group are listed and described as follows:

1. *Cole Sand* (Whitsett Zone).—The Cole sand is named from the Cole field, Webb and Duval Counties. It is a lenticular sand body varying in thickness from 10 to 25 ft. This sand produces in many scattered fields throughout the district, but the principal fields are the Cole, where a great amount of gas is produced with the oil, the Randado, in Jim Hogg County, where it produces oil, and the Eagle Hill, in Duval County, where it also produces oil. These three fields are good examples of Cole sand production.

2. *Chernosky Sand* (McElroy Zone).—The Chernosky sand is similar in lithological characteristics to the Cole sand and averages in thickness from 20 to 25 ft. It produces principally in the eastern part of Seven Sisters field in northern Duval County.

3. *Government Wells Sand* (McElroy Zone).—This sand is one of the most prolific in the entire district. The producing section is 150 ft.

thick, with individual sand members ranging from 15 to 35 ft. in thickness. Shale breaks from 10 to 20 ft. occur between the sands. The sand as a whole produces prolifically in the Government Wells, Sarnosa, Seven Sisters, Benavides, and Hoffman fields, all in Duval County.

4. *Loma Novia Sand* (McElroy Zone).—This sand ranges in thickness from 15 to 25 ft. and occurs approximately 130 ft. below the top of the Government Wells sand. It produces in the Loma Novia, Seven Sisters and Hoffman fields, all in Duval County.

5. *Upper Mirando Sand* (McElroy Zone).—The upper Mirando sand occurs at the base of the McElroy zone. The sand section is broken by intermittent beds of lignite and lignitic shales. Individual sand bodies range from 15 to 25 ft. in thickness. It produces oil and gas in the Mirando City, Aviators, West Cole, Killam, Oilton and Lopez fields, all in Webb County, and in the Escobas and Comitas fields in Zapata County.

6. *Lower Mirando Sand* (Caddell Zone).—This sand occurs at the top of the Caddell zone. It is separated from the upper Mirando sand by lignitic shales. The sand is similar in characteristics to the upper sand and usually produces in the same fields.

7. *O'Hern Sand* (Caddell Zone).—The O'Hern sand occurs at the base of the Caddell and is similar in characteristics to the upper sands. Its thickness is from 10 to 25 ft. It produces in the O'Hern extensions of the Cole field in Webb County.

Other Sands.—The Yegua, Cook Mountain and Mt. Selman formations also produce oil and gas in this district. The Yegua is the most productive zone, with its Cockfield member the most prolific. Sands found in the Yegua are the Pettus, "Jacobs," "Tuleta" and "Conroe," generally known sands, and there are other sands individually named in various fields, such as the "Navarro" sand, which is correlated with the Pettus sand in the Benavides field in Duval County, and the "Rosenburg" sand, also Pettus equivalent, in the Oilton field, Webb County.

Drilling during the year 1937 has been very active, the Yegua formation receiving more attention than previously, since it has been recognized by such discoveries as Benavides that the Yegua potentialities in that area are great. However, the Yegua, Cook Mountain and Mt. Selman produce only a small 15 per cent of the entire production in this district, the Jackson group producing the remaining 85 per cent. It is possible that deeper and extensive drilling in the future will open greater possibilities of the lower formations and, in turn, increase the amount of production from the lower group.

All of the sands in the district, regardless of the producing formation, are lenticular in shape and elongate in a north to northeasterly direction and wedge, or pinch out, very abruptly on the updip side, which is west to northwest. The yield per acre varies from 5000 to 20,000 bbl., and the average ultimate recovery per acre-foot of sand is estimated at 600 barrels.

*Stratigraphic Section of South Texas**

Series	Formation		Lithologic Character	Approximate Thickness, Ft.	Average Depth to Bottom of Each Member, Ft.
Recent to Pleistocene	Reynosa		Caliche	0–35	35
Pliocene	Goliad		Coarse gravel and gray sand usually covered with caliche mantel, interbedded with gray, mottled sticky clay	150	185
Miocene	Oakville		Coarse sand, brown to gray in color, associated with gray to red clay and shale	250	435
Oligocene	Catahoula tuff	Chusa	Fine-textured tuffaceous clays	500	935
		Soledad	Coarse sandstone, brownish gray to green, with volcanic ash, also large gravel and boulders	550	1485
		Fant	Volcanic tuff and light gray volcanic shales	150	1635
	Frio		Light gray sand, sandstone and sandy clays characterized by silicified wood	500	2135
Eocene	Jackson	Whitsett	Fossiliferous, green lignitic shale, fossiliferous, dark green shale, clay, sand and sandstone	350	2485
		McElroy	Fossiliferous, green and black shale with various beds of soft medium grained sands. This zone is characterized by *Textularia hockleyensis* and associated *Foraminifera*	850	3335
		Caddell	Gray black to dark green shales with beds of glauconitic sand. This zone is characterized by *Textularia dibollensis* and associated *Foraminifera*	150	3485
	Yegua	Upper and lower Cockfield	Micaceous chocolate brown to grayish black brittle shale with beds and lenses of medium-grained sand. This member of the Yegua formation contains an upper and lower horizon, the upper horizon being characterized by the "Pettus" sand and the lower horizon being characterized by the "Conroe" sand	1200	4685
		Cook Mountain	Micaceous sandy shales and sands, gray to grayish black in color	850	5535
		Mount Selman	Lignitic brown to brownish black shale with beds of brownish gray sand	1500	7035

* This description of formations includes only formations that have been penetrated by the drill or exposed on the surface. The surface formations in this district include formations ranging from the Pleistocene to the Eocene and contain clastic and pyroclastic sediments, varying in color, and composed of clays and shales, volcanic ash and tuff, sands and sandstones.

DUVAL COUNTY

Sweden Field

Discovery.—On Feb. 3, 1937, Hiawatha Oil Company's Southland Life No. 1 opened the Sweden field, southeast Duval County. It came in for 500 bbl. of 42.4° gravity oil in the "Conroe" sand, found at 5845 to 5869 ft., the top of the sand being 141 ft. below the top of the Cockfield.

The depth of the well is 5869 ft. and surface elevation is 385 ft.; the top of the Whitsett zone at 4342 ft., McElroy at 4650 ft. and Cockfield at 5704 ft. This discovery opened a new trend along the eastern side of the Mirando district, for until then the deepest production in the Mirando area was from 3600 feet.

2nd Sand.—On June 1, Hiawatha Oil Company's Southland Life No. 2 blew out while an attempt was being made to complete from 5100 to 5105 ft. in a sand in the McElroy zone. The well ran wild for a few hours, but finally was controlled and completed as a gasser with a little oil production. Before this completion, the test was drilled to 5939 ft. without favorable results and was plugged back to test several sands before finally making a completion in the 5100-ft. horizon.

3rd Sand.—In June, Hiawatha Oil Company's Herberger No. 2 flowed oil and water after perforating from 5080 to 5084 ft. This sand is placed in the McElroy zone and is considered as a different sand from that producing gas in the Southland Life No. 2 well. The Herberger well was drilled to 5914 ft., but failed to produce in the regular sand found in the discovery well.

Summary.—Since discovery, six oil wells, three gas wells and two dry holes have been completed in the Sweden field.

Benavides Field

Discovery.—On April 18, Frank Gravis & Doran's F. V. Puig No. 1, 1 mile south of Benavides and 4 miles northeast of Sweden field, was completed as a producer to discover the important Benavides field. The sand, which was found from 4730 to 4755 ft., is placed in the lower Government Wells sand zone and is called the "Gravis" sand. The elevation of this well is 396 ft., the top of the Whitsett is 3965 ft. and the top of the McElroy, 4361 feet.

2nd Sand.—On July 1, a new Jackson sand was found in Benavides when Atlee Parr No. 1 (Standard Oil of Kansas), 1 mile south of the field, was completed for an initial flow of 265 bbl. on ¼-in. choke in 24 hr. from sand at 4738 to 4743 ft. This horizon, named the "Parr" sand, in the McElroy zone in the upper Government Wells sand section, is 50 ft. above the "Gravis" pay.

3rd Sand.—On Aug. 1, Navarro Oil Company's E. M. Rossi No. 1 opened the third oil-producing horizon for Benavides when it flowed 44.7° gravity oil at the rate of 98 bbl. per day through ½-in. choke from a sand at 5330 to 5352 ft. This test originally was projected to the "Gravis" sand, but it found the "Gravis" horizon below water level and was carried to a total depth of 6179 ft. An electric log indicated the sand at 5330 to 5352 ft.; the well was plugged back to 5350 ft. and production was obtained. This new horizon is equivalent to the Pettus sand of Cockfield age; in this field it is called the "Navarro" sand.

TABLE 1.—*Oil and Gas Production in South Texas in* 1937

Line Number	Field, *County*	Age, Years to End of 1937	Area Proved, Acres			Total Oil Production, Bbl.			
			Oil	Gas	Total	To End of 1937	During 1936	During 1937	Daily Average during Nov. 1937
1	Alberoas, *Webb*	11	250	400	650	2,463,148	31,075	24,016	63
2	Alworth, *Jim Hogg*	11	80	570	650	27,793	320	0	0
3	Andrews, *Zapata*	14	0	2,000	2,000	Gas	Gas	Gas	Gas
4	Aviator, *Webb*	15	955	320	1,275	5,667,145	143,237	132,713	344
5	Barbacoas, *Starr*	4	60	580	640	27,804	4,330	4,335	10
6	Benavides (No. Sweden), *Duval*								
	3850–3900 ft. sand	0	0	40	40	.	0		
	4700–4750 ft. sand[1]	0	1,000	40	1,040		0		
	4750–4800 ft. sand	0	4,500	120	4,620		0		
	5300 ft. sand	0	350	0	350		0		
	Total	0	5,850	200	6,050	612,134	0	612,134	4,700
7	Blas Uribe, *Zapata*	4	0	80	80	Gas			
8	Calliham, *McMullen*	19	390	290	680	684,720	68,430	102,720	233
9	South Calliham, *McMullen*	3	40	440	480	Included in Calliham			
10	Carolina-Texas, *Webb*								
	1200 ft. sand	16	0	80	80	Gas	Gas	0	0
	2000 ft. sand	15	0	480	480	Gas	Gas	Gas	Gas
	2600 ft. sand	12	70	480	550 }	254,927	3,595	3,543	7
	3000 ft. sand	14	40	400	440 }				
	5000 ft. sand	2	0	20	20	Gas	Gas	Gas	Gas
	Total		110	1,460	1,570				
11	Charamousca, *Duval*	2	340	0	340	93,225y		93,225	299
12	Charco Redondo, *Zapata*								
	150–200 ft. sand	24	570	0	570	180,952	3,606	8,430	50
	900 ft. sand	9	0	60	60	Gas			
	Total	24	570	60	630	180,952	3,606	8,430	50
13	Clopton-Green, *Starr*	0	0	10	10	Gas	0	0	0
14	Cole group, *Webb-Duval*								
	1700 ft. sand	13	65	7,032	7,097		12,190		
	2300 ft. sand	10	0	2,066	2,066	Gas	Gas	Gas	Gas
	Cole O'Hern	10	2,270	120	2,390	3,894,381	1,183,759	2,054,541	5,902
	Cole Middle	2	20	160	180			10,850	23
	Cole Bruni	3	690	80	770	2,028,461	440,199	312,286	703
	East Bruni	0	140	0	140	112,961	0	112,961	452
	Total	13	3,185	9,458	12,643	6,035,803	1,636,148	2,490,638	7,080
15	Cole West, *Webb*	10	420	1,000	1,420	3,309,970	208,629	179,650	461
16	Colmena, *Duval*	3	240	400	640	142,076	13,345	127,265	343
17	Colorado, *Jim Hogg*	1	10	0	10	19,335	5,448	13,887	35
18	Comitas (Haynes), *Zapata*	3	1,025	40	1,065	838,333	252,947	537,170	652
19	Conoco Driscoll, *Duval*								
	2400 ft. sand	10		100	100	Gas	Gas		
	2900 ft. sand	8	120	160	280 }	946,895	135,753	301,998	1,049
	3400 ft. sand	3	230	720	950 }				
	Total	10	350	980	1,330	946,895	135,753	301,998	1,049
20	Crowther, *McMullen*	18	80	0	80	25,000	0	0	0
21	Cuellar, *Zapata*	10	340	220	560	2,487,954	42,522	40,959	107
22	Eagle Hill, *Duval*	4	340	160	500	652,251	137,792	122,588	320
23	El Mesquite, *Duval*	2	10	0	10	976	976	0	0
24	El Tanque, *Starr*								
	400 ft. sand	0	0	10	10	Gas		Gas	
	1700 ft. sand	0	270	20	290	70,969	0	70,969	283
	1800 ft. sand	0	10	0	10		0		0
	Total	0	280	30	310	70,969	0	70,969	283

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[1] Parr and Woodley sands combined.

TABLE 1.—(*Continued*)

Line Number	Total Gas Production,[5] Millions Cu. Ft.				Number of Oil and/or Gas Wells							Depth, Average in Feet		Oil Production Methods at End of 1937		Pressure, Lb. per Sq. In.[d]
						During 1937		At End of 1937						Number of Wells		
	To End of 1937	During 1936	During 1937	Maximum Daily during 1937	Completed to End of 1937	Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Gas Only	Total Producing	Bottoms of Productive Wells	To Top of Productive Zone	Flowing	Pumping	Initia
1	4,926	62	84	0.24	100	0	4	0	17	2	19	2,175	2,125	1	16	
2	55.5	0.64	0	0	15	2	0	7	0	0	0	1,030	1,020			
3					11	0			0	y	y	1,515	1,510			
4	11,334	286	265	0.79	216	0	12		77	0	77	1,660	1,525	0	77	
												715	685			
5	55	8	G728	G2.02	13	1	1	7	2	1	3	2,712	2,450	1	0	2,200
												5,398	5,376	1	0	
6		0			1	1	0	0	0	1	1	3,895	3,864			400
		0			25	25	0	0	24	1	25	4,755	4,730	23	1	460
		0			90	90	0	0	87	3	90	4,830	4,755	84	3	750
		0			8	8	0	0	8	0	8	5,352	5,330	7	1	400
	1,224	0	1,224	10	124	124	0	0	119	5	124			114	5	
7					2	0	0	2	0	0	0	1,840	1,825			
8	684	68	G120	G0.25	110	7	0	0	57	5	62	876 1,060	848 1,030	1	56	
9			G420	G1.1	14	6	0	2	2	6	8	790 1,058 1,236	780 1,052 1,230	0	2	
10																
					2	0	0	2	0	0	0	1,280	1,270			
			G990	G2.7	25	1	0	0	0	11	11	2,200	1,800			
			G84	G0.2	18	0	1	0	1	3	4	2,615	2,597	0	1	
					18	0	0	0	2	0	2	3,198	2,947	0	2	
					1	0	0	0	0	0	0	5,056	4,996			
			G1,074	2.9	64	1	1	0	3	14	17			0	3	
11	186		186	1	17	16	2	0	15	0	15	1,550	1,525	3	12	
12																
	361.9	7.2	16.8	0.1	162	7	10	0	47	0	47	200	150	0	47	
		0	0	0	3	0	0	0	0	0	0	995	989			
	361.9	7.2	16.8	0.1	165	7	10	0	47	0	47			0	47	
13					1	1	0	1	0	0	0	1,614	1,604			
14																
			G3,400	G9.5	110	0	0	6	0	78	78	1,730	1,722			
			G3,000	G8.3	33	1	0	0	0	30	30	2,450	2,314			
	3,894	1,183	G2,070	G5.6	229	67	0	0	227	1	228	2,815	2,800	177	50	
			G307	G0.4	2	0	0	2	1	1	2	2,960	2,950	0	1	
	2,028	440	312	1	70	7	0	14	42	0	42	3,450	3,400	12	30	
	226	0	226	1.5	14	14	0	0	14	0	14	3,431	3,415	11	3	
			G9,315	G25.4	458	89	0	22	284	110	394			200	84	
15	6,619	417	G659	G1.7	154	1	0	1	56	10	66	2,350	2,300	0	56	
16	284	26	254	0.7	34	27	2	1	22	9	31	1,550	1,486	5	17	
17	385	10.8	27.7	0.19	1	0	0	0	1	0	1	3,017	3,009	0	1	
18	838	252	G540	G0.66	164	52	0	1	162	1	163	1,000	815	5	157	
19																
	946	135	G601	G1.8	3	0	0	3	0	0	0	2,470	2,448	0	0	
					6	0	2	1	2	2	4	2,900	2,884	0	2	
					32	8	0	1	15	2	17	3,448	3,370	3	12	
	946	135	G601	G1.8	41	8	2	5	17	4	21			3	14	
20					23	0	0	0	0	0	0	520	500	0	0	
21	4,975	85	81	0.2	86	3	0	0	24	3	27	1,340	1,325	0	24	
22	652	137	122	0.32	23	0	3	2	18	0	18	1,470	1,450	0	15	
												2,150	2,120	0	3	
23	1.9	1.9	0	0	1	0	0	0	0	0	0	2,862	2,850	0	0	
24																
					1	1	0	0	0	1	1	429	425			
	141		141	0.56	9	9	0	0	9	0	9	1,775	1,739	5	4	200
					1	1	0	0	1	0	1	1,879	1,866	0	1	
	141		141	0.56	11	11	0	0	10	1	11			5	5	

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[d] Footnotes to column heads and explanation of symbols are given on page 313.

[5] All gas production figures are only of gas produced in solution with oil production, except those preceded by the letter G when production from gas wells is included.

TABLE 1.—(*Continued*)

Line Number	Character of Oil, Approx. Average during 1937			Producing Rock						Number of Dry and/or Near-dry Holes to End of 1937	Deepest Zone Tested to End of 1937	
	Gravity A.P.I. at 60° F.											
	Maximum	Minimum	Weighted Average	Name	Age[f]	Character[g]	Porosity[h]	Net Thickness, Average in Feet	Structure[i]		Name	Depth of Hole, Ft.
1	21.5	20.8	21	Cole (Jackson)	Eoc	Ss	Por	17	MF	14	Yegua	3,710
2	21	21	21	Upper Jackson	Eoc	Ss	Por	6	ML	18	Jackson	2,199
3		Gas		Jackson	Eoc	Ss	Por	5	MF	10	Jackson *y*	1,535*y*
4	22	20	21	Mirando (Jackson)	Eoc	Ss	Por	11	MF	21	Yegua	3,975
5		Gas		Catahoula	Olig	Ss	Por	10	AF	20	Yegua	5,640
	Gas and 24			Frio	Olig	Ss	Por	26	AF		Yegua	5,640
	58	58	58	Cockfield	Eoc	Ss	Por	22	AF	1	Yegua	5,640
6		Gas		Cole (Jackson)	Eoc	Ss	Por	22	MF	0	Lower Yegua	6,179
	44	42	43	Upper Gov. Wells	Eoc	Ss	Por	20	MF	0	Lower Yegua	6,179
	44	42.5	43.6	Lower Gov. Wells	Eoc	Ss	Por	25	MF	0	Lower Yegua	6,179
	45	44	44.7	Pettus (Cockfield)	Eoc	Ss	Por	22	MF	1	Lower Yegua	6,179
7		Gas		McElroy	Eoc	Ss	Por	15	*x*	6	Jackson	3,000
8	21	19.8	20	Hockleyensis	Eoc	Ss	Por	28	ML	47	Cook Mountain	3,000
	21	20.5	20.6	Pettus	Eoc	Ss	Por	10	ML			
9		Gas		Whitsett	Eoc	Ss	Por	10	MF	11	Carrizo	5,301
	22	21	21	Gov. Wells	Eoc	Ss	Por	6	MF			
		Gas		Loma Novia	Eoc	Ss	Por	6	MF			
10		Gas		Whitsett	Eoc	Ss	Por	10	AF	0	Mt. Selman	5,057
		Gas		McElroy	Eoc	Ss	Por	65	AF	6	Mt. Selman	5,057
	35	33	34	Cockfield	Eoc	Ss	Por	10	AF	10	Mt. Selman	5,057
	46	45	46	Upper Saline Bayou	Eoc	Ss	Por	50	AF	17	Mt. Selman	5,057
	Gas and 42.5			Mt. Selman	Eoc	Ss	Por	60	AF	1	Mt. Selman	5,057
										34		
11	21	20	20.5	Mirando	Eoc	Ss	Por	10	MF	9	Cook Mountain	3,892
12	17	16	17	Upper Jackson	Eoc	Ss	Por	8	ML	30	Cockfield	3,000
		Gas		Jackson	Eoc	Ss	Por	5	ML		Cockfield	3,000
13		Gas		Cole	Eoc	Ss	Por	10	*x*	0	Cook Mountain	4,620
14	23	22	22.5	Cole (Jackson)	Eoc	Ss	Por	8	A	32	Mt Selman	6,394
		Gas		McElroy	Eoc	Ss	Por	10	A	27	Mt. Selman	6,394
	29	28	28.5	Caddell	Eoc	Ss	Por	15	A	45	Mt. Selman	6,394
	36	36	36	Caddell	Eoc	Ss	Por	9	A	13	Mt. Selman	6,394
	42	41	41.7	Lower Yegua	Eoc	Ss	Por	14	A	27	Mt. Selman	6,394
	42	41	41.5	Lower Yegua	Eoc	Ss	Por	14	A		Mt. Selman	6,394
										144		
15	22	21	21.5	Mirando	Eoc	Ss	Por	11	ML	41	Mt. Selman	5,525
16	21	20	20	Whitsett	Eoc	Ss	Por	19	ML	14	Yegua	3,396
17	48	47	47.4	Cockfield	Eoc	Ss	Por	8	ML	6	Cockfield	3,202
18	23	21	21.5	Upper Jackson	Eoc	Ss	Por	10	ML	21	Cook Mountain	3,502
19	Gas and 22.5			Whitsett	Eoc	Ss	Por	20	A	1	Cook Mountain	4,695
	23	22	22.5	Hockleyensis	Eoc	Ss	Por	6	A	0	Cook Mountain	4,695
	34.5	33	33	Gov. Wells	Eoc	Ss	Por	10	A	7	Cook Mountain	4,695
										8		
20	18	18	18	Diboll	Eoc	Ss	Por	*y*	ML	16	*x*	*x*
21	23	21	22	McElroy	Eoc	Ss	Por	10	ML	32	Yegua	3,040
22	22.5	21.5	22	Whitsett	Eoc	Ss	Por	20	MF	16	Jackson	2,524
	23.5	23	23	Gov. Wells	Eoc	Ss	Por	20	MF			
23	43	43	43	Cockfield	Eoc	Ss	Por	12	ML	4	Yegua	3,502
24		Gas		Catahoula	Olig	Ss	Por	4	ML	0	Frio	2,379
	31.5	30.5	31	Frio	Olig	Ss	Por	14	ML	6	Frio	2,379
	30	30	30	Frio	Olig	Ss	Por	6	ML	1	Frio	2,379
										7		

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Age, Years to End of 1937	Area Proved, Acres			Total Oil Production, Bbl.			
			Oil	Gas	Total	To End of 1937	During 1936	During 1937	Daily Average during Nov. 1937
25	Escobas, *Zapata*	8	3,330	340	3,670	6,857,928	646,899	645,959	1,900
26	Ezzell, *McMullen-Live Oak*	0	1,850	80	1,930	83,075	0	83,075	912
27	Ezzell Ranch, *McMullen*	0	0	10	10	Gas			
28	Government Wells, *Duval*								
	North	9	4,680	400	5,080	34,060,489	5,810,076	3,761,256	9,363
	South	9	2,700	2,040	4,740			1,925,483	4,888
	Total	9	7,380	2,440	9,820	34,060,489	5,810,076	5,686,739	14,251
29	Guerra (Cuevitas), *Starr*	4	400	400	800	569,076	154,942	185,678	546
30	Hayden, *Starr*	1		20	20	Gas		Gas	
31	Henne-Winch-Farriss, *Jim Hogg*	13	720	440	1,160	3,206,290	1,126	2,379	5
32	Hoffman, *Duval*	4	1,250	320	1,570	915,939	281,580	628,873	2,206
33	South Hoffman, *Duval*	0	10	0	10	Included in Hoffman			
34	Ignacio, *Duval*	4	10	10	20				
35	Jacob,[2] *McMullen*	11	1,230	80	1,310	1,041,846	242,282	248,846	632
36	Jennings, *Zapata*	23	400	1,716	2,116			252,985	760
37	Killam, *Webb*	0	1,200	80	1,280	159,245	0	159,245	828
38	Kohler,[3] *Duval*	11	330	8,090	8,420	574,394	45,986	65,607	186
39	Labbe, *Duval*								
	2400 ft. sand	3	0	2,560	2,560	Gas	Gas	Gas	Gas
	2800–2900 ft. sand	0	330	160	490	72,118		72,118	339
	Total	3	330	2,720	3,050	72,118	Gas	72,118	339
40	Las Animas, *Jim Hogg*	0	10	60	70	300[4]	0	300[4]	0
41	Laurel, *Webb*	5	220	320	540	673,604	10,723	7,232	11
42	Leaseholders, *Webb*	15	10	20	30	25,000	0	0	0
43	Loma Alta, *McMullen*	2	20	0	20	64,633	28,381	23,480	56
44	Loma Novia, *Duval*	3	7,410	270	7,680	12,069,696	4,846,921	6,440,131	16,147
45	Loma Vista, *Duval*	1	10	0	10	11,374	5,425	5,949	7
46	Lopena, *Zapata*	3	0	1,040	1,040	Gas	Gas	Gas	Gas
47	Lopez, *Webb-Duval*	2	4,260	240	4,500	4,506,638	1,373,029	3,070,872	7,667
48	Los Olmos, *Starr*	12	175	175	350	523,355	55,943	50,153	125
49	Lundell, *Duval*	0	260	40	300	27,236	0	27,236	184
50	Martinez, *Zapata*	9	0	850	850	Gas	Gas	Gas	Gas
51	Mirando City, *Webb*	16	1,430	500	1,930	8,734,572	143,362	140,523	383
52	Mirando Valley, *Zapata*	16	140	200	340	643,087	10,047	9,579	21
53	Moca, *Webb*	5	80	20	100	736,231	147,426	139,748	260
54	Oilton, *Webb*								
	1900 ft. sand	0	1,420	60	1,480	111,549	0	111,549	1,127
	2400 ft. sand	0	0	20	20	Gas			
	Total	0	1,420	80	1,500	111,549	0	111,549	1,127
55	Palangana, *Duval*	9	50	0	50	9,846		0	0
56	Pena, *Duval*	5	0	40	40	Gas			

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[2] Includes North Jacob.
[3] Includes North Kohler.
[4] Production on tests.

TABLE 1.—(*Continued*)

Line Number	Total Gas Production,[5] Millions Cu. Ft.				Number of Oil and/or Gas Wells							Depth, Average in Feet		Oil Production Methods at End of 1937		Pressure, Lb. per Sq. In.[d]
						During 1937		At End of 1937						Number of Wells		
	To End of 1937	During 1936	During 1937	Maximum Daily during 1937	Completed to End of 1937	Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Gas Only	Total Producing	Bottoms of Productive Wells	To Top of Productive Zone	Flowing	Pumping	Initial
25	13,715	1,292	1,290	3.8	414	123	0	53	285	0	285	1,050 1,302 1,600	1,020 1,137 1,485	0	285	
26	83	0	83	0.91	55	55	0	0	51	4	55	1,550	1,490	3	48	
27					1	1	1	0	0	0	0	1,200	1,185			
28																
	34,060	5,810	G3,845 G2,033	G11.7 G6.3	819	12 5	0 0	8 8	468 264	5 7	473 271	1,575 2,350 2,450	1,550 2,280 2,380	20 12	448 252	
	34,060	5,810	G5,878	G18	819	17	0	16	732	12	744			32	700	
29	995	271	G758	G1.9	20	3	0	1	13	1	14	2,055 2,232	2,047 2,209	13	0	400
30					1	1	0	1	0	0	0	1,308	1,305			550
31	6,412	2.2	4.6	0.03	181	0	0	0	1	0	1	2,100	1,944	0	1	
32	915	281	G1,228	G4	126	73	0	10	104	5	109	2,570 2,757 2,895	2,550 2,749 2,865	81	23	
33					1	1	1	0	0	0	0	2,688	2,670	6	0	
34					2	0	0	0	0	0	0	2,126	2,115	0	0	
35	1,041	242	248	0.7	115	13	0	0	94	0	94	790 975 1,070	780 920 1,050	0 0	89 5	
36			G1,285	G3.5	92	11	0	8	80	4	84	1,200 1,953	905 1,410	5	75	
37	318	0	318	1.6	64	64	0	0	60	4	64	2,035	1,940	12	48	225
38	1,148	90	G1,751	G5	82	8	0	4	14	24	38	1,850 2,500 2,800	1,748 2,438 2,613	6	8	
39																
			G480	G1.3	5	0	0	1	0	4	4	2,460	2,453			890
	144		144	0.7	22	22	0	0	18	4	22	2,900	2,800	8	10	260
	144		G624	G2	27	22	0	1	18	8	26			8	10	
40					4	4	0	0	1	3	4	1,828	1,782	1	0	200
41	1,247	20	G428	G1.2	33	0	0	1	11	2	13	366 1,777 2,275	360 1,770 2,244	0	11	
42	50	0	0	0	3	0	0	0	0	0	0	1,055	1,049	0	0	
43	64.6	28.3	23.4	0.07	2	0	0	0	2	0	2	2,207	2,195	0	2	50
44	12,069	4,846	G6,482	G20.9	758	83	0	34	719	5	724	2,705 2,900	2,550 2,846	133	586	
45	22.6	10.8	11.8	0.1	1	0	0	0	1	0	1	2,922	2,914	0	1	
46			G3,189	8.7	13	3	0	0	0	13	13	2,170	2,147			925
47	9,013	2,746	6,140	14.3	369	96	0	20	344	0	344	2,144	2,126	165	179	760
48	1,046	111	G109	G0.28	89	1	0	0	74	1	75	694	371	0	74	120
49	54	0	54	0.5	13	13	0	0	12	1	13	1,530	1,513	9	3	640
50			681	1.8	20	0	0	0	0	20	20	1,927	1,921			620
51	17,469	286	298	G0.75	295	1	7	0	91	1	92	1,540 1,935	1,530 1,925	0	91	
52	1,286	20	G37	G0.09	49	0	9	0	9	1	10	1,423	1,416	0	9	
53	736	147	139	0.45	12	0	0	0	10	0	10	910	900	0	10	
54																
	222	0	G232	G2.5	74	74	0	0	71	3	74	1,943	1,914	21	50	300
					1	1	0	0	0	1	1	2,435	2,407			850
	222	0	222	2.5	75	75	0	0	71	4	75			21	50	
55					5	0	0	0	0	0	0	455 2,744	450 2,730	0 0	0 0	60
56					1	0	0	0	0	0	0	932	915			700

TABLE 1.—(*Continued*)

Line Number	Character of Oil, Approx. Average during 1937			Producing Rock						Number of Dry and/or Near-dry Holes to End of 1937	Deepest Zone Tested to End of 1937	
	Gravity A.P.I. at 60° F.											
	Maximum	Minimum	Weighted Average	Name	Age[f]	Character[g]	Porosity[h]	Net Thickness, Average in Feet	Structure[i]		Name	Depth of Hole, Ft.
	20	20	20	McElroy	Eoc	Ss	Por	6	ML			
25	22	20.5	21	McElroy	Eoc	Ss	Por	14	ML	103	Yegua	3,500
	22	21	21	McElroy	Eoc	Ss	Por	7	ML			
26	20	19.5	19.7	Loma Novia	Eoc	Ss	Por	11	ML	3	Yegua	3,108
27		Gas		Gov. Wells	Eoc	Ss	Por	15	ML	1	Jackson	1,285
28												
		Gas		Cole	Eoc	Ss	Por	17	MF			
	24	22	23	Gov. Wells	Eoc	Ss	Por	19	MF	78	Mt. Selman	5,858
	26	25	26	Loma Novia	Eoc	Ss	Por	11	MF			
29	32	32	32	McElroy	Eoc	Ss	Por	8	ML	18	Cockfield	3,600
	35	34	34.8	McElroy	Eoc	Ss	Por	23	ML			
30		Gas		Frio	Olig	Ss	Por	3	ML	0	Frio	1,444
31	22	20.5	21	Hockleygnsis	Eoc	Ss	Por	16	MF	60	Yegua	3,546
	23	23	23	Hockleyensis	Eoc	Ss	Por	20	ML			
32	24	22.5	23	Gov. Wells	Eoc	Ss	Por	8	ML	43	Cockfield	3,605
	27.5	27	27.1	Loma Novia	Eoc	Ss	Por	30	ML			
33	27	27	27	Hockleyensis	Eoc	Ss	Por	18	ML	4	Cockfield	3,514
34	22	22	22	Upper Gov. Wells	Eoc	Ss	Por	11	ML	14	Caddell	3,101
		Gas		Mirando	Eoc	Ss	Por	8	ML			
35	21	20	20.5	Pettus	Eoc	Ss	Por	7	ML	59	Cook Mountain	3,171
	21.5	20.5	21	Cockfield	Eoc	Ss	Por	8	ML			
36	23	21	22	McElroy	Eoc	Ss	Por	48	A	23	Reklaw	4,645
	23	23	23	Jackson-Yegua	Eoc	Ss	Por	23	A			
37	22.5	22	22	Mirando	Eoc	Ss	Por	12	ML	6	Cockfield	2,657
	22	21	21.5	Cole	Eoc	Ss	Por	12	ML			
38	23	22	22.5	Gov. Wells	Eoc	Ss	Por	12	ML	44	Carrizo	7,723
	24	21	21.6	Mirando	Eoc	Ss	Por	29	ML			
39												
		Gas		Hockleyensis	Eoc	Ss	Por	7	ML	7	Yegua	4,054
	27.5	26	27	Loma Novia	Eoc	Ss	Por	19	ML	1	Yegua	4,054
										8		
40	22	22	22	Cole	Eoc	Ss	Por	22	A	1	Yegua	3,808
		Gas		Frio	Olig	Ss	Por	6	MF			
41		Gas		Mirando	Eoc	Ss	Por	6	MF	29	Mt. Selman	3,165
	49.5	48	49	Cockfield	Eoc	Ss	Por	7	MF			
42	22	22	22	McElroy	Eoc	Ss	Por	6	ML	36	Yegua	3,034
43	21	21	21	Chernosky	Eoc	Ss	Por	12	MF	6	Cockfield	2,766
44	27	25	26	Loma Novia	Eoc	Ss	Por	25	ML	47	Cook Mountain	4,200
	23	22	22.5	Mirando	Eoc	Ss	Por	15	ML			
45	26	26	26	Loma Novia	Eoc	Ss	Por	7½	ML	9	Cook Mountain	4,732
46		Gas		Queen City	Eoc	Ss	Por	23	A	3	Mt. Selman	3,502
47	23	21.5	22	Mirando	Eoc	Ss	Por	18	ML	19	Upper Saline Bayou	3,437
48	19	18	18.5	Frio	Olig	Ss	Por	17	MF	66	McElroy	2,612
49	22	21	21	Cole	Eoc	Ss	Por	10	MF	3	Jackson	2,698
50		Gas		Hockleyensis	Eoc	Ss	Por	6	ML	15	Yegua	3,514
51	22	21	21.5	Hockleyensis	Eoc	Ss	Por	10	ML	69	Reklaw	5,000
	46	44.5	45	Cockfield	Eoc	Ss	Por	10	ML			
52	22	20.5	21	Hockleyensis	Eoc	Ss	Por	7	ML	71	Cook Mountain	3,660
53	22	21	21	McElroy	Eoc	Ss	Por	10	MF	5	Upper Saline Bayou	2,178
54												
	23	21.5	22	Mirando	Eoc	Ss	Por	29	ML	5	Yegua	3,000
		Gas		Cockfield	Eoc	Ss	Por	28	ML	0	Yegua	3,000
										5		
55	16	16	16	Catahoula	Olig	L	Cav	5	DS	75	Cook Mountain	5,454
	45	45	45	Jackson	Eoc	Ss	Por	14	DS	1		
56		Gas		Frio	Olig	Ss	Por	17	MF	2	Caddell	3,620

Extension to 3rd Sand.—Lonnie Glasscock's A. Farias No. 4 extended the Pettus or "Navarro" sand production 4700 ft. east when it encountered a sand section at 5358 to 5368 ft., and was completed as an oil producer in December. The test is important because it greatly extended the producing area in the deeper sand.

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Age, Years to End of 1937	Area Proved, Acres			Total Oil Production, Bbl.			
			Oil	Gas	Total	To End of 1937	During 1936	During 1937	Daily Average during Nov. 1937
57	Peters, *Duval*	5	250	1,400	1,650	90,874	18,962	66,479	161
58	Peyote, *Jim Hogg*	5	0	20	20	Gas			
59	Piedre Lumbre, *Duval*	2	640	200	840	507,283	199,731	299,838	916
60	Pietras Pintas, *Duval*	32	120	0	120	150,622	3,049	7,444	69
61	Rancho Solo, *Duval*								
	1800 ft. sand	1	200	100	300	16,744	Gas	16,744	38
	2500 ft. sand	2	0	20	20	Gas	Gas		
	Total	2	200	120	320	16,744	Gas	16,744	38
62	Randado, *Jim Hogg*	12	765	435	1,200	4,465,779	113,508	100,245	272
63	Reiser, *Webb*	29	20	1,270	1,290	4,000	0	0	0
64	Rhode, *McMullen*	1	0	640	640	Gas	Gas	Gas	Gas
65	Ricaby, *Starr*	0	20	0	20	5,299	0	5,299	7
66	Rio Grande City, *Starr*	5	140	0	140	319,982	83,373	82,102	127
67	Roma, *Starr*								
	200 ft. sand	10	0	280	280	Gas			
	3500 ft. sand	8	20	0	20	16,193	956	911	1
	Total	10	20	280	300	16,193	956	911	1
68	Sam Fordyce, *Starr-Hidalgo*	3	1,500	900	2,400	5,226,764	1,775,792	2,015,646	4,191
69	North Sam Fordyce, *Starr*	0	10	0	10	7,528	0	7,528	26
70	Santo Domingo, *Starr*	2	0	20	20	Gas			
71	Sarnosa, *Duval*	5	690	180	870	1,834,764	319,965	304,216	765
72	Seven Sisters, *Duval*								
	1700 ft. sand	0	10	0	10	713	0	713	0
	2100–2200 ft. sand	2	140	40	180	256,271	129,600	115,544	296
	2400 ft. sand	2	3,730	40	3,770	4,964,274	1,770,229	3,078,509	7,803
	2600 ft. sand[6]	2	340	20	360	373,955	92,435	281,520	774
	2500 ft. sand[6]	0	160	20	180	132,480	0	132,480	363
	Total	2	4,380	120	4,500	5,727,693	1,992,264	3,608,766	9,236
73	South Seven Sisters, *Duval*								
	1500 ft. sand	0	20	0	20	8,138	0	8,138	23
	2600 ft. sand	0	40	0	40	21,314	0	21,314	46
	Total	0	60	0	60	29,452	0	29,452	69
74	S.R.C., *Duval*	7	80	0	80	203,371	3,847	0	0
75	Sweden, *Duval*								
	5000 ft. sand	0	20	0	20	3,680	0	3,680	20
	5100 ft. sand	0	0	20	20	Gas	0		
	5800 ft. sand	0	100	40	140	49,108	0	49,108	200
	Total	0	120	60	180	52,788	0	52,788	220
76	Thomas-Lockhart, *Duval*	0	100	0	100	11,990	0	11,990	94
77	Villa, *Zapata*	5	0	120	120	Gas			
78	Wentz, *McMullen*	6	0	80	80	Gas			
79	Woods, *Starr*	2	0	120	120	Gas			
80	Wray, *Zapata*	4	0	80	80	Gas			
	Total	32	57,975	45,344	103,319	118,892,757	21,003,758	29,533,280	

[6] Due to elevation.

4th Sand.—Woodley Petroleum Company's No. 1 Vaello, 5000 ft. east of the discovery well, was completed in a sand approximately 130 ft. structurally above the "Gravis" sand at 4798 to 4811 ft., to prove production in this fourth producing level for Benavides. The lower sands carried salt water. The total depth of the well is 6007 feet.

TABLE 1.—(*Continued*)

Line Number	Total Gas Production,[5] Millions Cu. Ft.				Number of Oil and/or Gas Wells							Depth, Average in Feet		Oil Production Methods at End of 1937		Pressure, Lb. per Sq. In.[d]
						During 1937		At End of 1937						Number of Wells		
	To End of 1937	During 1936	During 1937	Maximum Daily during 1937	Completed to End of 1937	Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Gas Only	Total Producing	Bottoms of Productive Wells	To Top of Productive Zone	Flowing	Pumping	Initia
57			G214	G0.56	17	4	0	1	7	1	8	1,760 2,451 2,635	1,750 2,431 2,610	7	0	750
58					1	0	0	0	0	0	0	2,294	2,224			
59	507	199	G782	G2.2	66	23	0	0	53	6	59	1,331 1,974 2,139	1,324 1,962 2,133	19	34	500 400
60	301	7	14.8	0.2	25	0	0	0	2	0	2	580 3,623	180 3,462	0 0	0 2	500
61																
	33.5		33.5	0.3	10	9	0	5	4	1	5	1,838	1,826	4	0	
			0	0	1	0	0	0	0	0	0	2,569	2,555			800
	33.5		33.5	0.3	11	9	0	5	4	1	5			4	0	
62	8,931	227	200	0.5	191	0	4	4	104	0	104	1,275	1,225	0	104	
63					18	0	0	0	0	0	0	1,010	390	0	0	
64			260	0.7	6	3	0	0	0	6	6	1,822	1,810			650
65	10	0	10	0.05	2	2	1	0	1	0	1	1,317 1,611	1,312 1,604	0 0	1 0	175 235
66	639	166	164	0.25	30	0	2	2	24	0	24	1,450	1,350	0	24	
67																
					4	0	0	0	0	0	0	200	192			
	32				1	0	0	0	1	0	1	3,566	3,560	0	1	
	32				5	0	0	0	1	0	1			0	1	
68	5,226	1,775	G2,555	G5.6	198	17	0	3	184	11	195	2,753 2,853 3,074	2,737 2,831 2,950	137	47	400 1,050 1,250
69	7.5	0	7.5	0.02	1	1	0	0	1	0	1	3,039	2,995	1	0	460
70					1	0	0	1	0	0	0	2,616	2,461			1,050
71	1,834	320	G340	G0.8	56	7	1	5	50	0	50	2,412	2,350	0	50	
72																
	1.4	0	1.4	0.04	1	1	0	0	1	0	1	1,720	1,710	1	0	225
	256	129	115	0.58	14	2	0	1	13	0	13	2,225	2,112	8	5	
	4,964	1,770	G3,258	8.3	374	36	0	3	342	1	343	2,485	2,470	178	164	625
	373	92	G461	G1.2	35	20	0	1	34	1	35	2,690	2,660	20	14	200
	132	0	132	0.36	16	16	0	0	16	0	16	2,565	2,540	14	2	
	5,726.4	1,991	3,967.4	10.4	440	75	0	5	406	2	408			221	185	
73																
	16	0	16	0.12	1	1	0	0	1	0	1	1,566	1,559	0	1	
	42	0	42	0.24	2	2	0	0	2	0	2	2,656	2,646	0	2	
	58	0	58	0.36	3	3	0	0	3	0	3			0	3	
74	406	7.6	0	0	6	0	0	0	0	0	0	1,740	1,731	0	0	
75																
	7.2	0	7.2	0.04	1	1	0	0	1	0	1	5,091	5,072	1	0	
					1	1	0	1	0	0	0	5,116	5,100			
	98.3	0	98.3	0.4	7	7	0	0	5	2	7	5,869	5,845	3	0	300
	105.5	0	105.5	0.44	9	9	0	1	6	2	8			6	0	710
76	23.9	0	23.9	0.21	4	4	0	0	4	0	4	4,672	4,659	4	0	
77					3	0	0	0	0	0	0	1,664	1,657			1,450
78					3	0	0	0	0	0	0	382	370			375
79					4	0	0	0	0	0	0	975	963			200
80					3	0	0	0	0	0	0	370	348			460
					6,693	1,181	63	229	4,580	313	4,893			1,227	3,353	150

5th Sand.—Standard of Kansas' Walstead No. 2 found a possible producing sand when it found hard rock at 3903 to 3906 ft., gas sand at 3906 to 3913 ft. and gas and oil sand at 3916 to 3921 ft. A drill-stem test showed 150 ft. of oil at 390 lb. pressure in six minutes. Coring ahead, salt-water sand was found at 3921 to 3925 ft. This well was later

TABLE 1.—(*Continued*)

Line Number	Character of Oil, Approx. Average during 1937			Producing Rock						Number of Dry and/or Near-dry Holes to End of 1937	Deepest Zone Tested to End of 1937	
	Gravity A.P.I. at 60° F.											
	Maximum	Minimum	Weighted Average	Name	Age[f]	Character[g]	Porosity[h]	Net Thickness, Average in Feet	Structure[i]		Name	Depth of Hole, Ft.
57		Gas		Cole	Eoc	Ss	Por	5	ML	8	Yegua	3,309
		Gas		Gov. Wells	Eoc	Ss	Por	20	ML			
	23.5	22.5	23	Mirando	Eoc	Ss	Por	15	ML			
58		Gas		Gov. Wells	Eoc	Ss	Por	70	ML	2	Cockfield	3,210
59		Gas		Cole	Eoc	Ss	Por	7	ML	7	Yegua	3,250
	21	20	20.5	Gov. Wells	Eoc	Ss	Por	12	ML			
	23	22	22.5	Loma Novia	Eoc	Ss	Por	6	ML			
60	13	13	13	Catahoula	Olig	Ss	Por	20	DS	36	Yegua	4,502
	50	42	47	Hockleyensis	Eoc	Ss	Por	26	DS			
61	22	21	21.5	Cole	Eoc	Ss	Por	12	ML	0	Yegua	3,777
		Gas		Gov. Wells	Eoc	Ss	Por	14	ML	2	Yegua	3,777
62	21	20	20.5	Whitsett	Eoc	Ss	Por	9	MF	49	Mt. Selman	5,222
63	Gas and		16	Jackson	Eoc	Ss	Por	15	ML	54	Mt. Selman	3,247
64		Gas		Cole	Eoc	Ss	Por	12	MF	4	Yegua	3,356
65	24	24	24	Frio	Olig	Ss	Por	5	ML	3	Frio	2,011
	30	30	30	Frio	Olig	Ss	Por	7	ML			
66	28	27	27.3	Frio	Olig	Ss	Por	8	MF	46	Jackson	3,258
67		Gas		Frio-Jackson	Olig-Eoc	Ss	Por	8	A	9	Reklaw	4,827
	35	35	35	Queen City	Eoc	Ss	Por	6	A		Reklaw	4,827
										9		
68	21.5	21	21	Frio	Olig	Ss	Por	16	A	35	Vicksburg	5,395
	25	23.5	24	Frio	Olig	Ss	Por	22	A			
	25	24	24.5	Frio	Olig	Ss	Por	20	A			
69	23	23	23	Frio	Olig	Ss	Por	35	A	0	Frio	3,039
70		Gas		Frio	Olig	Ss	Por	155*x*	A	3	Jackson	4,003
71	22.5	21.5	22	Hockleyensis	Eoc	Ss	Por	40	MF	22	Yegua	4,073
72	21	21	21	Cole	Eoc	Ss	Por	10	MF	38	Lower Saline Bayou	4,404
	21	20	20.5	Chernosky	Eoc	Ss	Por	20	MF		Lower Saline Bayou	4,404
	23.5	22	23	Gov. Wells	Eoc	Ss	Por	15	MF		Lower Saline Bayou	4,404
	27.5	26.5	27	Loma Novia	Eoc	Ss	Por	15	MF		Lower Saline Bayou	4,404
	23	23	23	Mirando	Eoc	Ss	Por	10	MF		Lower Saline Bayou	4,404
73	22	22	22	Frio	Olig	Ss	Por	7	MF	0	Loma Novia	2,665
	27	27	27	Loma Novia	Eoc	Ss	Por	10	MF	1	Loma Novia	2,665
										1		
74	21	20	20.8	McElroy	Eoc	Ss	Por	9	MF	5	Jackson	2,331
75	46	46	46	Upper Gov. Wells	Eoc	Ss	Por	19	MF	0	Cook Mountain	6,531
		Gas		Lower Gov. Wells	Eoc	Ss	Por	16	MF	0	Cook Mountain	6,531
	58	58	58	Cockfield	Eoc	Ss	Por	24	MF	2	Cook Mountain	6,531
										2		
76	57	56	56.8	Pettus	Eoc	Ss	Por	13	MF	8	Cook Mountain	5,502
77		Gas		McElroy	Eoc	Ss	Por	7	ML	3	Cook Mountain	3,000
78		Gas		Whitsett	Eoc	Ss	Por	12	N	8	Jackson	1,654
79		Gas		Frio	Olig	Ss	Por	12	A	3	Jackson	3,360
80		Gas		Jackson	Eoc	Ss	Por	22	ML	4	Yegua	2,000
										1,809		

completed in the "Gravis" sand as an oil producer. This 3900-ft. level is the Cole sand of Jackson age, and was developed as a producing level by the completion of the Circle Oil Company's Merle West No. 1-A as a gasser during the last week in December.

First Twin Producer.—In mid-September, in the completion of Gravis and Doran's V. Puig No. 5, Benavides had its first twin producer, 760 ft. east of the discovery and 50 ft. east of Puig No. 4. The test completed in the "Gravis" sand at 4790 to 4799 ft. and flowed 4 bbl. per hour

TABLE 2.—*Summary of Drilling Operations in South Texas*

Important Wildcats Drilled in 1937

	County	Well Name and Location	Total Depth, Ft.	Surface Formation	Deepest Horizon Tested
1	Duval	Southland Life No. 1 A. Poquita Grant	5869	Goliad	Cockfield
2	Duval	Smith Corkill No. 2 Section 498	2780	Catahoula	Hockleyensis
3	Duval	V. Puig Tract A. Garcia Heirs Grant	4766	Goliad	Jackson
4	Duval	Parr Tract Valentine Survey	4672	Goliad	Pettus (Cockfield)
5	Duval	Southland-Life No. 2 S. Flores Grant	5939	Goliad	Cockfield
6	Duval	Faris No. 1-A S. Flores Grant	4804	Goliad	Jackson
7	Duval	Puig No. 1 S. Andres Grant	4800	Goliad	Jackson
8	Duval	Labbe No. 2 Section No. 1	3249	Oakville	Jackson
9	Duval	Lundell No. 1 Section 140	1520	Catahoula	Cole (Jackson)
10	Duval	Lundell No. 2 Section 140	1528	Catahoula	Cole (Jackson)
11	Duval	F. G. Wilson No. 1 Blk 9 S. Flores Grant	4775	Goliad	Jackson
12	Duval	A. Parr No. 1 San Andres Grant	4747	Goliad	Jackson
13	Duval	Rossi No. 1 Sec. 11 S. Flores Grant	6179	Goliad	Yegua
14	Duval	F. V. Puig No. 1 San Andres Grant	6006	Goliad	Yegua
15	Duval	R. V. DePuig No. 1 Section 8	5437	Goliad	Upper Cockfield
16	Duval	Southland Life No. 1 A. Poquita Grant	4775	Goliad	Jackson
17	Duval	F. V. Puig No. 12 San Andres Grant	4801	Goliad	Jackson
18	Duval	Miller No. 2 A. Poquita Grant	5866	Goliad	Cockfield
19	Duval	Peters No. 1 Section 32	1898	Goliad	Jackson
20	Duval	G. Rodrigues No. 2 Section 212	2818	Oakville	Jackson
21	Duval	Peters No. 2 Survey No. 38	2742	Catahoula	Jackson
22	Duval	Rodriguez No. 1 Survey 212	2657	Oakville	Jackson
23	Duval	Rodriguez No. 2 Survey 212	2665	Oakville	Jackson
24	Duval	Warden & Draught No. 3 Survey 151	1533	Frio	Jackson
25	Starr	Hayden No. 1 Blk. 4 Survey 47	1444	Catahoula	Frio
26	Starr	Yturria No. 1 Porcion 100	3039	Goliad	Frio
27	Starr	Ricaby No. 1 Porcion 83	1400	Goliad	Frio
28	Starr	B. D. Wood Estate No. 1 Porcion 84	1754	Goliad	Basal Frio
29	Starr	Ricaby No. 3 Porcion 83	1611	Goliad	Frio
30	Starr	Green No. 1 Blk 5 Porcion 81	4620	Catahoula	Cook Mountain
31	Starr	Slick-Estate No. 1 Section 485	5607	Goliad	Jackson
32	Starr	Starr Co. Cattle No. 1-A Porcion 89	5640	Goliad	Cockfield
33	Starr	C. P. Wardner No. 2 Porcion 84	503	Goliad	Catahoula
34	Starr	Valadez No. 1 Porcion 84	1873	Goliad	Basal Frio
35	Webb	Laurel Bros. No. 1 Survey 333	2038	Goliad	Jackson
36	Webb	M. G. Martin No. 1 Survey 458	1943	Goliad	Jackson
37	Webb	Laurel Bros. No. 1 Survey 1006	1930	Goliad	Jackson
38	Webb	Garza Estate No. 2 Section 48	2110	Catahoula	Jackson
39	Webb	Garcia No. 7 Section 786	2009	Goliad	Jackson
40	Webb	A. M. Bruni No. 50 Blk. 10 Sec 8	3431	Goliad	Lower Yegua
41	Webb	Garcia & Villareal No. 1 Sec 338	2525	Goliad	Rosenburg (Cockfield)
42	Webb	M. G. Martin No. 2 Survey 458	1927	Goliad	Jackson
43	McMullen	Ezzell No. 1 T. Adams Survey	1285	Undiff't'd Jackson	Jackson
44	McMullen	Jacob Corp No. 2 B—GH & HR Survey	1074	Undiff't'd Jackson	Pettus (Cockfield)
45	McMullen	Claunch-Tract No. 1 M. Hely Survey	1058	Undiff't'd Jackson	Hockleyensis
46	McMullen	Ezzell No. 3 Section 3 Adams Survey	5301	Undiff't'd Jackson	Carrizo
47	McMullen	Ezzell No. 4 Russell Survey	1534	Catahoula	Loma Novia
48	Jim Hogg	R. Holbein No. 1 B Las Animas Grant	1789	Goliad	Cole (Jackson)
49	Jim Hogg	R. Holbein No. 1 A Las Animas Grant	3808	Goliad	Yegua
50	Zapata	J. Garcia No. 1 B Share 3	1054	Undiff't'd Jackson	McElroy

TABLE 2.—(*Continued*).

Important Wildcats Drilled in 1937

	Drilled by	Initial Production per Day		Choke or Bean, in Fractions of an Inch	Pressure, Lb. per Sq. In.[d]		Remarks
		Oil, U. S. Bbls.	Gas, Millions of Cu. Ft.		Casing	Tubing	
1	Hiawatha Oil Co.	500		5/32	1200	710	Discovery Sweden field
2	Argo Oil Co.	130		1/4	450	350	Discovery South Hoffman
3	Frank Gravis	1250		1/8	950	750	Discovery North Sweden (Benavides)
4	Thomas Est.—Lockhart Bros.	125	5	3/8	1750	1450	Discovery Thomas-Lockhart field
5	Hiawatha Oil Co.		15	1/8	1300	1500	N. E. extension Sweden
6	Russ Petroleum Co.	450		1/8	780	700	N. W. extension Benavides
7	Parr Oil Co.	375		1/4	800	450	3/4-mile ext. Benavides
8	Magnolia Pet. Co.	35		3/8	200	75	Discovery oil production in Labbe
9	Gov. Wells Co.		11	3/8	640	640	Discovery Lundell field
10	Gov. Wells Co.	320		3/8	375	110	Discovery oil production Lundell
11	Reynosa Oil Co.	750		5/32	1020	525	Extension Benavides
12	Std. of Kansas	530		5/32	750	425	Discovery Parr sand Benavides
13	Navarro Oil Co.	150		1/2	250	125	Discovery Cockfield production Benavides
14	Woodley Pet. Co.	200		15/64	610	350	Extension Benavides
15	V. L. Blanchard	325		5/32	1075	450	1 1/4-mile extension Benavides
16	Std. of Kansas	460		3/16	750	500	South extension Benavides
17	Parr & Delaney	500		1/4	300	650	N. E. extension Benavides
18	Hiawatha Oil Co.	50	5	1/8	800	500	S. W. extension Sweden
19	Cox & Hamon	50		1/4	300	150	1 1/2-mile extension Rancho Solo
20	Sun Oil Co.	450		1/8	710	210	1 mile S. W. extension Labbe
21	Gier & Kone		26	1/8	300	375	N. W. extension Peters field
22	A. J. Brinkoeter	100		3/8	150	100	Discovery South Seven Sisters
23	A. J. Brinkoeter	75		3/8	150	100	Extension South Seven Sisters
24	N. V. Duncan	120		1/4	320	120	Extension, new sand, Charamousca
25	Howard Bass		5	5/16	550	350	Discovery Hayden gas field
26	Graham & Wood	350		3/8	600	400	Discovery North Sam Fordyce
27	Moss & Heard	100		1/8	250	175	Discovery Ricaby field
28	G. E. Dodd	850		5/16	150	200	Discovery El Tanque field
29	Moss & Heard	90		3/16	425	235	Discovery 1600-ft. sand, Ricaby
30	J. H. Clopton		5	1/8	425	425	Discovery Clopton-Green
31	Davenport & Transwestern						Dry hole showings at D. D. Ranch
32	K. E. Merren	800		1/8–5/32	2350	2200	Discovery Cockfield production—Barbacoas
33	C. Wood	2	1	1/4	150	160	Discovery 400-ft. sand El Tanque
34	Dean Brothers	30		1/4	250	175	Discovery 1800-ft. sand
35	O. W. Killam	192		1/4	300	225	Discovery Killam field
36	J. R. B. Moore	120		1/4	400	300	Discovery Oilton field
37	J. B. Blanchard	20	1	1/4	400	325	South extension Oilton
38	E. J. Pearl		3	1/8	300	375	N. E. extension Carolina-Texas
39	O. W. Killam	126		1/4	450	300	South extension Killam
40	O. W. Killam	450		3/16	850	650	Discovery East Bruni field
41	Moore & Meaders		12	1/8	850	850	Extension Oilton 1 mile north
42	Gypsy Oil Co.	253		1/4	400	250	West extension Oilton
43	E. M. Jones		2	3/8	430	470	Discovery Ezzell Ranch gas field
44	Loma Oil Co.	50		1/4	175	75	Discovery 1000-ft. production Jacob
45	L. J. Synder et al.	75		1/4	125	25	Discovery oil South Calliham
46	E. M. Jones	75	10	1/8	800	500	Deepest test South Calliham
47	E. M. Jones	480		1/4	310	85	Discovery Ezzell oil field
48	Darby Pet. Co.		20	1/2	300	200	Discovery Las Animas field
49	Darby Pet. Co.		12	1/8	400	300	N. E. extension Las Animas
50	Matthews & Calloway	50		1/4	125	25	Extension Escobas oil in gas area

	In Proven Fields	Wildcats
Number of wells drilling Dec. 31, 1937	76	27
Number of oil wells completed during 1937	1094	35
Number of gas wells completed during 1937	87	20
Number of dry holes completed during 1937	254	228

TABLE 3.—*Wells Drilled to 5000 Feet and Below during 1937*

County	Field	Company and Well	Depth, Ft.	Last Formation	Results
Duval	Wildcat	Hiawatha Oil Co. Southland No. 3	7005	Cook Mt.	Dry hole
Duval	Wildcat	V. L. Blanchard R. V. DePuig No. 1	5437	Cockfield	Oil production
Duval	Wildcat	Penn-Palagana Oil Co. C. K. Gravis No. 1	6165	Yegua	Dry hole
Duval	Wildcat	H. J. Porter C. D. Sevier No. 1	6012	Cockfield	Dry hole
Duval	Wildcat	Porter, Talbot, & Dorn Montmayer No. 1	5676	Cockfield	Dry hole
Duval	Wildcat	Hiawatha Oil Co. Southland No. 1	5869	Cockfield	Oil production
Duval	Sweden	Hiawatha Oil Co. Herberger No. 1	5896	Cockfield	Oil production
Duval	Wildcat	H. F. Grimm E. Mew No. 1	5005	Cockfield	Dry hole
Duval	Wildcat	Hiawatha Oil Co. Southland No. 2	5939	Cockfield	Gasser
Duval	Sweden	Hiawatha Oil Co. Herberger No. 2	5914	Cockfield	Oil production
Duval	Wildcat	G. V. Viteri E. E. Cadena No. 1	6636	Cook Mt.	Dry hole
Duval	Wildcat	Navarro Oil Co. E. M. Rossi No. 1	6179	Yegua	Oil production
Duval	Wildcat	Tex-Canadian Oil Co. M. J. Luby No. 1	5503	Cockfield	Dry hole
Duval	Sweden	Hiawatha Oil Co. M. M. Miller No. 2	5866	Cockfield	Oil production
Duval	Sweden	King Drilling Co. A. Parr No. 1	6531	Yegua	Dry hole
Duval	Benavides	Woodley Petroleum Co. F. V. Puig No. 1	6006	Yegua	Oil production
Duval	Benavides	Russ Petroleum Co. A. Farias No. 8	5377	Cockfield	Oil production
Duval	Benavides	Sun Oil Company Barton Est. No. 1	5672	Cockfield	Dry hole
Duval	Sweden	Hiawatha-Oskness Miller No. 1	5887	Cockfield	Oil production
Duval	Benavides	Russ Petroleum Co. Rossi No. 2-a	5370	Cockfield	Gasser
Duval	Benavides	Woodley Petroleum Co. M. West No. 1	5374	Cockfield	Oil production
Duval	Sweden	Hiawatha Oil Co. Miller No. 3	5934	Cockfield	Gasser with oil
Duval	Benavides	Circle Oil Co. M. West No. 1	5370	Cockfield	Oil production
Duval	Thomas-Lockhart	Taylor Refining Co. A. Parr No. 1	5162	Cockfield	Oil and gas
Duval	Benavides	Frank Gravis V. Puig No. 1-a	6018	Yegua	Dry
Duval	Thomas-Lockhart	Lockhart Bros. Rogers No. 1	5502	Cook Mt.	Dry hole
Duval	Benavides	Humble Oil & Ref. Co. Moyer No. 1	5393	Cockfield	Oil production
Duval	Benavides	Navarro Oil Co. West No. 1	5339	Cockfield	Oil production
McMullen	Wildcat	E. M. Jones H. Ezzell No. 3	5301	Carrizo	Gasser
Starr	Wildcat	F. Davenport Slick-Urschel-Slick No. 1	5607	Jackson	Dry
Starr	Barbacoas	K. E. Merren Starr Co. Cattle No. 1	5381	Yegua	Dry
Starr	Barbacoas	K. E. Merren Starr Co. Cattle No. 1-A	5640	Yegua	Oil production
Starr	Wildcat	Transwestern Oil Co. Slick No. 2	5883	Jackson	Dry
Webb	Wildcat	Wilcox Oil & Gas Puig Bros. No. 1	5750	Mt. Selman	Dry
Webb	Wildcat	Wilcox Oil & Gas D. B. Dunbar No. 1	5355	Mt. Selman	Dry
Webb	Wildcat	O. W. Killam Fee No. 1	5245	Mt. Selman	Dry
Webb	Wildcat	Taylor Refining Co. Parr No. 2	6015	Mt. Selman	Dry

through $\frac{5}{32}$-in. choke with 450 lb. tubing pressure and 400 lb. casing pressure. Puig No. 4 made 28 bbl. in 6 hr. through $\frac{3}{16}$-in. choke at 4739 to 4750 ft. in the "Parr," or upper, sand. With five producing levels already proven in the Benavides field, and only one considered to be an edge sand, it is interesting to observe that it is locally possible for a

TABLE 4.—*Total Number of Wells Drilled in South Texas Fields during 1937, by Counties*

Field	Oil	Gas	Dry
DUVAL COUNTY			
Benavides (N. Sweden)	119	5	1
Charamousca	16	0	4
Colmena	19	8	7
Conoco Driscoll	8	0	0
Eagle Hill	0	0	0
El Mesquite	0	0	0
Government Wells (North and South)	16	1	8
Hoffman	72	1	10
Ignacio	0	0	0
Kohler	5	3	5
Labbe	18	4	1
Loma Novia	79	4	13
Loma Vista	0	0	3
Lopez	45	5	4
Lundell	12	1	2
O'Hern (Cole)	23	0	6
Palangana	0	0	0
Pena	0	0	0
Peters	1	3	1
Pietras Pintas	0	0	0
Piedre Lumbre	22	1	2
Rancho Solo	8	1	0
Sarnosa	7	0	6
Seven Sisters	73	2	11
South Seven Sisters	3	0	1
South Hoffman	1	0	4
S R C	0	0	0
Sweden	6	3	2
Thomas-Lockhart	4	0	5
Total	557	42	96
JIM HOGG COUNTY			
Alworth	0	2	3
Colorado	0	0	1
Henne-Winch-Farriss	0	0	1
Las Animas	1	3	1
*Peyote	0	0	0
Randado	0	0	3
Total	1	5	9
MCMULLEN COUNTY			
Calliham	7	0	3
Crowther	0	0	1
Ezzell	31	4	2
*Ezzel Ranch	0	1	1
Jacob	8	0	5
Loma Alta	0	0	1
North Jacob	5	0	6
*Rhode	0	3	0
South Calliham	4	2	3
*Wentz	0	0	0
Total	55	10	22
STARR COUNTY			
Barbacoas	1	0	3
*Clopton-Green	0	1	0
Cuevitas	3	0	0
El Tanque	10	1	7
*Hayden	0	1	0
Los Olmos	0	1	5
Ricaby	2	0	3
Rio Grande City	0	0	5
Roma	0	0	1
Sam Fordyce	3	0	0
North Sam Fordyce	1	0	0
*Santo Domingo	0	0	0
*Woods	0	0	0
Total	20	4	24
WEBB COUNTY			
Albercas	0	0	0
Aviator	0	0	1
Carolina-Texas	0	1	1
Bruni	6	1	14
East Bruni	14	0	
O'Hern	44	0	8
Cole (2300 ft. sand)	0	1	0
Killam	60	4	6
Laurel	0	0	0
Leaseholders	0	0	0
Lopez	44	2	5
Mirando City	0	1	1
Moca	0	0	0
Oilton	71	4	5
Reiser	0	0	0
West Cole	0	1	3
Total	239	15	44
ZAPATA COUNTY			
*Andrews	0	0	1
*Blas Uribe	0	0	0
Charco Redondo	7	0	1
Comitas	51	1	14
Escobas	122	1	28
Jennings	11	y	y
*Lopeno	0	3	2
*Martinez	0	0	1
Mirando Valley	0	0	0
Cuellar	0	3	4
*Villa	0	0	0
*Wray	0	0	1
Total	191	8	52
Grand total for 1937†	1063	84	247

* Gas field.

† There were also 20 oil wells, and 1 dry hole completed in the Live Oak County portion of Ezzell field, and 11 oil wells, 3 gas wells and 6 dry holes completed in the Hidalgo County portion of Sam Fordyce field.

"four-well" drilling program to be adapted to each drilling unit or 10 acres.

Limits of Field to Northeast.—Limits of Benavides field production were defined to the northeast by Sun Oil Company's F. S. Barton No. 1, a northeasterly outpost that drilled to 5672 ft. in lower Cockfield and was abandoned. It showed no odor in a sandy section at 4794 to 4804 ft., salt water at 4934 to 4956 ft. and again at 5010½ to 5026½ ft. This test is supposed to be about 100 ft. lower structurally than the west outpost, indicating a cross fault at this point, which may extend in a northeasterly direction and be a definite limit to the field.

Thus defined to the northeast, search for Pettus sand production in Benavides will probably be centered around the western and eastern portions of the producing area. Several wells have been completed at this level on the western side of the field. As a result, it now appears that this sand gives promise of being rather an important zone. This field continues to be the most active in the Mirando district, with a series of offset and twin wells drilled to the several sands already proven. The producing area has been widened to include several thousands of acres. The field proper continues its development to the west, southwest and southeast, with outpost wells finding the sands sufficiently high to indicate that the area will be further widened in those directions.

Summary.—Since discovery there have been 119 oil wells, 5 gas wells and 1 dry hole completed in the Benavides field.

Thomas-Lockhart Field

Discovery.—On April 18, No. 1 Parr, belonging to Thomas Estate and Lockhart Bros., 18 miles north of Benavides, was completed as an oil producer and discovered the so-called Thomas-Lockhart field when it flowed 5 bbl. of 58° gravity oil per hour through ⅜-in. choke from upper Pettus sand at 4659 to 4672 feet.

Summary.—Since discovery four oil wells and five dry holes have been completed in the Thomas-Lockhart field.

Lundell Gas and Oil Field

Discovery.—On June 15, Government Wells Company's Lundell No. 1 discovered the Lundell field when it came in as an 11,000,000-cu. ft. gasser spraying several barrels of oil per day through ¾-in. choke at 640 lb. working pressure. Cole sand was topped at 1513 ft., the first 2 ft. being hard gas cap and the next 5 ft. good gas and oil sand. Total depth was 1520 ft. with casing set at 1513 ft. This well is 1½ miles west of Government Wells field proper, but is looked upon as an entirely new discovery and, further, lines up a new trend of Cole-sand production, being on trend with Colmena field, to the southwest, from which oil and gas are produced from the same Cole horizon, and with Piedre Lumbre field, several miles to the northeast, which produces gas in this horizon.

Lundell No. 2, drilled 1200 ft. southeast of No. 1, later proved up oil production with a flow of 23 bbl. per hour from sand at 1518 to 1528 feet.

Summary.—Since discovery there have been 12 oil wells, 1 gas well and 2 dry holes completed in the Lundell field.

South Hoffman Field

Discovery.—Argo Oil and John Clopton's Smith Corkhill No. 2 was completed March 2, pumping 130 bbl. of fluid on a 24-hr. test to open this pool from sand logged at 2670 to 2688 ft. This formation is just above upper Government Wells sand and is probably a stray sand, as the later unsuccessful wells drilled seemed to substantiate, since the Corkhill No. 2 was the only oil or gas well in this sand. A lower Government Wells sand at 2775 to 2780 ft. also failed to produce.

South Seven Sisters Field

Discovery.—An area to the south and west of the Seven Sisters field was discovered as being productive when the A. J. Burkoeter's Rodriguez No. 1 made 4 bbl. of oil per hour from 10 ft. of sand at 2646 to 2656 ft. in the Loma Novia zone. This test was about one mile from the Seven Sisters production and is between that field and the Loma Novia field. Several dry holes were drilled in the past between this new discovery and the Seven Sisters field which proves the area to be a separate one from the Seven Sisters. This discovery was made in April.

2nd Sand.—On May 28, A. J. Burkoeter's Rodriguez No. 3 produced oil from the Frio sand from 1559 to 1566 ft., which opened a new sand in the South Seven Sisters field. In the Seven Sisters field this same sand showed gas. The Frio is about 200 ft. above the top of the Jackson and this discovery opens a vast area for exploration as possible shore-line production. Several wells in this general vicinity showed oil in fair quantities in this horizon 5 or 6 years ago; however, completions were unsuccessful. The Frio has produced both oil and gas in the Driscoll field about 25 miles due south, also in the Mount Lucas field in Live Oak County, and Sandia field in Jim Wells County, which are about 35 miles to the northeast of this new find. However, neither of these fields is as high updip as this new producer.

Summary.—Since discovery three oil wells and one dry hole have been completed in the South Seven Sisters field.

New Oil Sands in Existing Fields

Labbe Field.—Oil production in the Labbe field was finally found in the Loma Novia sand when Magnolia Petroleum Company's A. L. Labbe No. 2 was completed on Feb. 4 as a pumper, making 35 bbl. of 27° gravity oil per day from 2900-ft. sand. This discovery is 1¼ miles northeast of the Labbe gas production.

Humble Oil & Refining Company's Roos Bros. No. 1 provided a ¼-mile northwest extension to this sand when it produced 50 bbl. of oil per day on pump; also the Sun Oil Company's Rodriguez No. 2 cored sand at 2799 to 2818 ft., set casing at 2800 ft. and flowed 65 bbl. of fluid on a 5-hr. test through ⅛-in. choke, registering 260 lb. tubing pressure and 710 lb. casing pressure. This is an extension of more than one mile southwest to the Magnolia's Labbe No. 2 well.

Seven Sisters Field.—Two new oil sands were found in the old Seven Sisters field—the Mirando, discovered on March 10 by the Humble Oil & Refining Company's Dowdy Fee No. 5, when it was completed for 11 bbl. of oil per hour, 6 per cent salt water, through ⅜-in. choke, in sand at 2558 to 2565 ft. Gas sand was found at 2556 to 2558 ft. This is the Mirando sand of lower McElroy age. This well is on the northwest side of Seven Sisters field and is the fourth sand for the field. The sand appears to follow a northeast-southwest trend along the western side of the field, just as the Loma Novia sand does on the eastern side of the structure.

The second sand discovered is the Cole sand, found at 1710 to 1720 ft. by the Wellington Oil Company's J. F. Welder Heirs No. 8-D, on the extreme west side of the Seven Sisters field. This well was completed as a producer and flowed 195 bbl. per day.

Sand and Extension for Charamousca.—On Feb. 14, N. V. Duncan's Warden & Draught No. 3 discovered production in the Mirando sand from 1527 to 1533 ft., which opened a new producing horizon in the Mirando zone west of the Charamousca field, which was discovered last year. This discovery is in the extreme northwestern portion of Duval County, about ½ mile west of the original Charamousca discovery. These two areas produce at about the same depth from the surface of the ground, but structurally the Duncan well is about 100 ft. deeper. The Charamousca discovery had a thin sand lens and produced oil for a short period. More than 50 ft. of sand was logged in a near-by well in the sand level at which the Duncan well is producing. This established another trend of production at a shallow level in this field, in which 16 oil producers and 4 dry holes were completed during 1937.

Hoffman Field.—A new sand about 100 ft. shallower than the regular Government Wells sand was discovered in December when Cox & Hamon's Cuellar Bros. No. 2 pumped 100 bbl. of oil per day through perforations at 2550 to 2570 ft. This well failed to produce in the Loma Novia sand at 2807 ft. and was plugged back to this upper sand.

Extensions to Established Areas

Rancho Solo Field.—On Oct. 11, Cox & Hamon's W. R. Peters No. 1 extended the Rancho Solo field 1½ miles northeast when it was completed for 2 bbl. of crude per hour, with considerable gas, from the Cole sand at 1826 to 1838 feet.

JIM HOGG COUNTY

Las Animas Field

Discovery.—Darby Petroleum Company's Holbein No. 1-B was completed as a gasser in the Cole sand at 1782½ to 1788 ft. This production is on a rather large structure. Offset, No. 1-A Holbein, northeast of discovery, found the Cole sand 15 ft. higher than No. 1-B at 1765 to 1782 ft. This pool is 5 miles east of Henne, Winch & Farriss field, 14 miles west of Hebbronville, and is on strike with production in the Cole O'Hern district of Duval and Webb Counties.

Oil was found in this same Cole sand by Darby Petroleum Company's Holbein No. 2-B, which cored gas sand at 1806 to 1812 ft. and oil sand from 1812 to 1828 ft. On completion it flowed 106 bbl. in 12 hours.

Summary.—Since discovery one oil well, three gas wells and one dry hole have been completed in the Las Animas field.

MCMULLEN COUNTY

Ezzell Ranch

Discovery.—E. M. Jones' Ezzell No. 1, completed in March, discovered a gas sand on the Ezzell Ranch when it was completed as a gasser in the Government Wells sand. Total depth was 1285 ft., where it topped the Mirando sand, which showed salt water. This gasser later blew out and was killed and is not now producing. One other well was drilled in the area and was abandoned as dry. No other completions have been made, and at present only the abandoned gas well remains as evidence of a possibility of future production.

Ezzell Field

Discovery.—E. M. Jones' Ezzell No. 4 opened the Ezzell field in June from the Loma Novia sand at 1523 to 1533 ft. The nearest Loma Novia sand production is in Labbe and Seven Sisters fields, Duval County, which are 35 miles southwest of this new discovery. Ezzell Ranch gas field is 2 miles north of this discovery.

Harry Ezzell's Fee No. 7-A, completed in November, flowed 1027 bbl. of oil in 24 hr. through open tubing in sand at 1489 to 1500 ft. This being on the northwest side of the producing area, it indicates that tests on the top of the structure will be comparatively large flowing wells.

This field was carried into Live Oak County by R. P. Holland's No. 1 Matkin, ¾ mile northeast of the E. M. Jones production in the field proper. Sands were found at 1485 to 1489 and 1496 to 1501 ft. This well made 180 bbl. daily on pump.

Summary.—Since discovery 31 oil wells, 4 gas wells and 2 dry holes have been completed in the Ezzell field, McMullen County, and 20 oil wells and 1 dry hole in the Ezzell field in Live Oak County.

New Sands in Existing Fields

South Calliham Field.—On May 4, about 4000 ft. west of South Calliham gas field, Snyder et al. Claunch No. 1 was completed for 75 bbl. of oil from Government Wells sand at 1052 to 1058 ft. This established oil production in an area that heretofore produced gas.

Edwin M. Jones' Harry Ezzell No. 3 drilled to 5301 ft., plugged back and completed at 1230 to 1236 ft. for 10,000,000 cu. ft. of gas on May 24, to discover the Loma Novia gas-producing sand in South Calliham.

STARR COUNTY

Hayden Gas Field

Discovery.—In January Howard Bass' Hayden et al. No. 1 opened a new shallow gas area 5 miles northeast of Rio Grande City in Starr County. Production of several million cubic feet of gas was from sand at 1305 to 1308 ft. The well was drilled to 1444 ft. and plugged back to the upper portion of the Rio Grande City sand, which is in the Frio formation. This is the only test in this field to date.

Ricaby Field

Discovery.—Moss & Heard's S. B. Ricaby No. 1, completed in February, opened the Ricaby field from Frio sand at 1312 to 1317 ft. This area is 4 miles northeast of the Rio Grande City field.

2nd Sand.—A second sand at 1604 to 1611 ft. was found by Ricaby No. 3, an oil producer, one mile east of No. 1. The 1300-ft. sand produced only in the discovery.

Summary.—Since discovery two oil wells and three dry holes have been completed in the Ricaby field.

El Tanque (S. Ricaby) Field

Discovery.—D. E. Dodd Trustee's D. B. Wood Estate No. 1 flowed at the rate of 12 to 15 bbl. of 31° gravity oil per hour through 3/16-in. choke at 1739 to 1754 ft. from Frio to discover the El Tanque field, on May 25. This is 4 miles northeast and 1½ miles southeast of Rio Grande City and 1½ miles southeast of the Ricaby shallow field.

2nd Sand.—Gas sand was found in October in Catahoula at 425 to 429 ft., by C. Wood's Wardner Trustee No. 2.

3rd Sand.—In November, Dean Bros. M. Valadez No. 1 pumped 20 bbl. of oil daily after finding production in Frio sand at 1868 to 1872 feet.

Summary.—Since discovery 10 oil wells, 1 gas well and 7 dry holes have been completed in the El Tanque field.

Clopton-Green

Discovery.—Clopton & Reeds' Green No. 1 came in as a gasser at 1604 to 1614 ft. in Cole sand in May. Ricaby and El Tanque (S. Ricaby) align with Clopton-Green to form a northwest-southeast trend. The Green well is in the Jackson formation and Ricaby and El Tanque fields are producing from the lower Frio. Indications of faulting between fields are evident. This test, the only one in this field to date, was shut down shortly after it was brought in.

North Sam Fordyce Field

Discovery.—Graham & Woods' Yturria No. 1 opened the North Sam Fordyce field in the lower Frio formation from a sand at 2995 to 3039 ft. The well flowed 350 bbl. per day of 23° gravity oil through a $\frac{3}{8}$-in. choke. This has been the only productive well to date in this field, which is approximately 3000 ft. northwest of the Sam Fordyce field proper.

New Sands in Existing Fields

New Sam Fordyce Sand.—A new producing horizon for Sam Fordyce was opened in March by Henshaw Bros. in E. F. de Flores No. 1 at the north end of the field. The well was drilled to 4140 ft. and plugged back to 3110 ft., perforated at 3064 to 3074 ft. in Frio sand and made a gasser with 1250 lb. closed-in. pressure. This sand is 100 ft. deeper than the deepest producing level in the field at the time.

New Sand for Barbacoas.—K. E. Merren's Starr County Cattle Company's No. 1-A discovered Yegua (Cockfield) sand production in Barbacoas field in June, when it flowed 396 bbl. of 58° gravity amber colored fluid on a 24-hr. gauge through chokes ranging from $\frac{1}{32}$ to $\frac{5}{32}$ in., under tubing pressure of 2200 lb. and 2350 lb. casing pressure. The total depth was 5418 ft. and perforations were at 5376 to 5398 ft. Heretofore, all oil had been from the Catahoula and Frio. This well later sanded up and was then deepened and recompleted in sand logged at 5417 to 5427 ft.; total depth, 5640 ft.

WEBB COUNTY

Killam Field

Discovery.—O. W. Killam's Laurel Bros. No. 1 flowed 192 bbl. of Mirando type crude on April 20, to discover the Killam pool. Sand was found at 2031 to 2036 ft., casing set at 2026 ft. This test was drilled in the vicinity of several failures and is lower structurally than wells that showed both oil and water in Mirando sand but apparently in a different lens. Like the Lopez field, along the same trend, Killam, with its shallow sand, low-cost operation, even sand conditions and high recovery, has proved itself important. This field is 2 miles northeast of Oilton and 2 miles east of Laurel field, which produces in a lower Jackson sand.

Summary.—Since discovery, 60 oil wells, 4 gas wells and 6 dry holes have been completed in Killam field.

Oilton Field

Discovery.—J. R. B. Moore's Martin No. 1 flowed 5 bbl. of Mirando grade crude per hour at 1943 ft. to discover, in August, the important Oilton field, which, at that time, was rated as a major 3½-mile southwest extension to Killam. This test found broken Mirando sand at 1914 to 1935 ft. and a good sand from 1935 to 1943 feet. Together with Killam, this field forms a producing area approximately 5 miles long.

2nd Sand.—Moore & Meaders' Garcia & Villareal No. 1, one mile north of Oilton field, established production during December in the "Rosenburg," or Cockfield, sand, when it flowed 12,000,000 cu. ft. of gas and showed 850 lb. pressure. The production was from perforations at 2430 to 2435 ft. The top of the sand was at 2407 feet.

Summary.—Since discovery 71 oil wells, 4 gas wells and 5 dry holes have been completed in Oilton field.

East Bruni Field

Discovery.—O. W. Killam opened the East Bruni field when his A. M. Bruni No. 50 was completed in Yegua sand at 3431 ft. This was thought to be an extension to the regular Bruni field, but it is regarded as a new field, although production in both fields is obtained from the same sand.

Summary.—Since discovery 14 oil wells have been completed in the East Bruni field.

Extension to Established Areas

Carolina-Texas.—E. J. Pearl's la Garza No. 2 cored oil sand at 2100 to 2107 ft. and came in as a gasser producing 3,000,000 cu. ft., 2 miles northeast of Carolina-Texas field. A sand previously had been cored at 1966 to 1972 ft., which carried odor of oil and salt water. It is on trend with the Lopez field.

ZAPATA COUNTY

Extensions to Established Areas

Escobas Field.—The Escobas field was given an extension in Matthews Drilling Company and Earl Calloway's No. 1-B Justina Garcia, which was completed as an oil producer from the McElroy (Government Wells) sand at 1054 ft. This sand formerly had produced only gas.

SUMMARY

The developments in South Texas for the year 1937 can be summarized as follows: There were 17 new field discoveries, of which 14 have produced oil and 3 have produced only gas. These three gas fields, Hayden, Ezzell Ranch and Clopton-Green, have been shut in during the year, each having had one producer. One oil discovery, the South Hoffman field, with one producer, has also been shut down.

New sand discoveries in existing fields totaled 9 (1 in Labbe field, 2 in Seven Sisters field, 1 in Charamousca field and 1 in Hoffman field, all in Duval County; 2 in South Calliham field, McMullen County; 1 in Sam Fordyce field, Starr County; and 1 in the Barbacoas field, Starr County). There were many extensions to old and new fields by wells that were regarded as wildcats but that extended the productive area. There were 38 such productive wildcats, and from this number 10 were completed as extensions to the new Benavides field. In all 283 wildcat tests were drilled in South Texas in 1937, of which 35 produced oil, 20 were completed as gas wells and 228 were abandoned as dry holes.

There were 1094 oil wells, 87 gas wells and 254 dry holes completed in South Texas fields during the year; including 11 oil wells, 3 gas wells and 6 dry holes drilled in the Hidalgo County portion of Sam Fordyce field, and 20 oil wells and 1 dry hole completed in the Live Oak County portion of the Ezzell field (see Table 4).

The production of oil during the year, according to prorated allowable, totaled 29,533,280 bbl. against the 1936 production figure of 21,003,758 bbl., an increase of 8,529,522 bbl.

The outlook for 1938 is much more promising for an increase in activity than the outlook at the beginning of 1937. Wildcat wells continue to hold the spotlight and many will be drilled for new sands in old fields as well as on new blocks. Geophysical work is being conducted by many companies over the entire area, mostly with gravity apparatus.

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West Texas Oil Developments in 1937

By Peter P. Gregory* and Basil B. Zavoico,† Members A.I.M.E., and John G. H. Crump‡

(New York Meeting, February, 1938)

West Texas was the scene of greatly increased oil activity during 1937, producing 75,743,000 bbl.[1] in that year as compared with 61,901,000 bbl.[2] in 1936, an increase of 22.36 per cent. The annual total of wells completed increased from 1586[3] in 1936 to 2806[2] in 1937, an increase of 76.92 per cent. Of the total completions in 1937, 2464 were oil wells,[2] 11 gas wells[2] and 331 dry holes.[2] The marked increase in the number of oil wells completed in West Texas during 1937 had a substantial effect upon the daily average production per well, which decreased 20.84 per cent from December 1936, when a total of 5310 wells[3] produced 5,236,467 bbl.[3] for an average of 31.81 bbl. per well per day to December 1937, when 7571 wells[2] with a total production of 5,910,257 bbl.[2] averaged 25.18 bbl. per well per day.

Drilling blocks and checkerboard acreage were being acquired following geophysical work in the northern end of the Permian Basin area, composed of Bailey, Cochran, Hockley, Yoakum and Terry Counties, presaging extension of active development northward. During 1937, at one time 30 geophysical crews were working in West Texas, and an average of 15 to 20 crews was active in this area throughout the year.

Discoveries

Wasson-Denver Field.—Wasson-Denver field in Gaines and Yoakum Counties was the outstanding field discovery of the year. Production is from porous limestone found at about 5000 ft., and an average well is good for from 300 to 500 bbl. of crude oil per day through ¾-in. choke. The discovery well was drilled by A. G. Carter and others on the Wasson Ranch, Gaines County, and the field has since been extended into Yoakum County. At the year's end 21 wells had been completed, producing

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[1] U. S. Bureau of Mines.

[2] *The Oil and Gas Journal.*

[3] R. W. Byram: Texas Railroad Commission Schedule.

TABLE 1.—*Oil and Gas Production in West Texas*

Line Number	*County,* Field	Age, Years to End of 1937	Area Proved, Acres				Total Oil Production, Bbl.	
			Oil	Oil and Gas[a]	Gas	Total	To End of 1937	During 1936
1	*Andrews:* Deep Rock (Walker Furman.)	7	2,500	0	0	2,500	1,497,328	389,003
2	Emma	0	40	0	0	40	y	y
3	Means	3	10,520[1]	0	0	10,520[1]	1,484,105y	456,509
4	Parker	3	160	0	0	160	37,424	13,957
5	*Cochran:* Duggan	1	640	0	0	640	33,048	3,747
6	*Crane-Upton:* Church-Fields-McElroy-McClintic	12	13,500	0	0	13,500	104,905,687	4,491,732
	Crane: Sand Hills (Tubb)							
7	Permian	7	2,740[2]	0	0	2,740[2]	545,054y	93,093
8	Ordovician	2	160	0	0	160	117,765	14,721
9	*Crockett:* Todd Ranch[3]	6	360	0	120	480	3,842	3,779
10	World-Powell	12	2,000	0	0	2,000	5,965,506	390,024
11	*Dawson:* Albaugh	1	160	0	0	160	753	0
12	Wilson	0	40	0	0	40	2,039	0
13	*Ector:* Addis (S. Cowden)	5	1,500	0	40	1,540	778,067	93,093
14	Cowden (North)		y	y	y	y	y	2,166,279
15	Foster	2	5,120	y	y	5,120	939,794	107,773
16	Goldsmith[4]	3	20,000±	20,000±	0	20,000	3,800,189	429,316
17	Harper	4	5,200	0	0	5,200	356,712	35,187
18	Landreth-Johnson	3	40	0	0	x	38,375	10,279
19	*Ector-Crane:* Penn-Jordan-Waddell	10	16,000	0	500	16,500	18,881,692	2,922,779
20	*Gaines:* Landreth-Kirk	1	x	x	x	x	0	0
21	Seminole	1	2,560	2,560	640	3,200	28,053	1,361
22	*Gaines-Yoakum:* Wasson-Denver	½	y	y	y	y	189,973	0
23	*Garza:* Emerald (Garza)	13	320	0	0	320	76,310	18,304
	Glasscock-Howard: Chalk Roberts							
24	1400-ft. pay	11	1,500	0	0	1,500	4,755,224	466,000x
25	1700-ft. pay	12	4,000	0	0	4,000	11,104,482	650,000x
26	2200-ft. pay	9	8,000	0	0	8,000	31,105,722	3,907,000x
27	2500-ft. pay	10	1,600	0	0	1,600	9,465,909	620,000x
28	3000-ft. pay	10	4,000	0	0	4,000	21,056,002	1,100,000x
29	*Glasscock:* Dodson-Duffy:	1	160	0	0	160	3,024	0
30	*Hockley:* Slaughter	0	y	y	y	y	10,275	0
31	*Howard:* Iatan-Denman	12	6,500	0	0	6,500	7,773,560	2,291,054
32	*Irion:* Irion Co	8	340	0	0	340	119,783	14,368
33	*Loving:* Mason	1	200±	0	0	200±	88,560	0
34	Wheat	12	4,500	0	0	4,500	6,921,665	604,496
35	*Mitchell:* Westbrook	17	4,000	0	0	4,000	8,406,571	319,980
36	*Pecos:* Masterson	8	640	0	0	640	512,812	194,156
37	McKinzie	2	160	0	0	160	2,447	1,072
38	Netterville	1	1,300±	0	0	1,300±	161,540	62,542
39	Pecos Valley	9	1,800	0	80	1,880	809,080	137,371
40	Pryor-Richards	9	160	0	0	160	27,229	1,200
	Taylor Link							
41	Sand		450y	0	0	450y	493,291y	15,000y
42	Lime	9	1,160	0	0	1,160	4,235,236x	433,265
	Yates							
43	Sand	4	700	0	0	700	303,113	96,846
44	Lime	11	20,000	0	0	20,000	232,920,321	12,214,156
45	*Pecos:* Tobarg	8	1,200	0	0	1,200	3,855,080[5]	777,366
46	White and Baker	3	320	0	640	960	3,096	1,123

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[a] Footnotes to column heads and explanation of symbols are given on page 313.

[1] Means field: producing 2800 acres; proven for production 5520 acres; 2920 acres semiproven, total 10,520 acres.

[2] Sand Hills field: producing 640 acres; proven for production 890 acres; 1210 acres semiproven, total 2740 acres.

[3] Abandoned Feb. 1, 1937 account depleted state of production.

[4] Includes Davidson-Cole, Cummins, Scharbauer and Goldsmith.

[5] Total to end of 1936 only.

100 bbl. per day each under proration. Wells are expensive, owing to the thick, hard rock section, and an average expenditure of about $45,000 is necessary. In spite of costs, the offset obligations and expiring leases will doubtless cause a large number of wells to be drilled during 1938 in

TABLE 1.—(*Continued*)

Line Number	Total Oil Production, Bbl.		Total Gas Production, Millions Cu. Ft.				Number of Oil and/or Gas Wells								Depth, Average in Feet	
								During 1937		At End of 1937						
	During 1937	Daily Average during Nov. 1937	To End of 1937	During 1936	During 1937	Maximum Daily during 1937	Completed to End of 1937	Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Oil and Gas[b]	Producing Gas Only	Total Producing	Bottoms of Productive Wells	To Top of Productive Zone
1	508,654	1,468	y	y	y	y	33	13	1	y	31	0	1	32	4,628	4,348
2	y	y	x	x	x	x	1	0	1	0	0	0	0	0	4,342	4,110
3	797,306	1,803	1,475,000	y	y	y	54	30	0	y	52	0	2	54	4,535	4,475
4	12,473	17	0	0	0	0	2	0	0	0	2	0	0	2	4,790	4,627
5	29,301	106	x	x	x	x	3	1	0	0	3	0	0	3	5,068	5,025
6	4,520,758	11,970	y	y	y	y	440	26	0	20y	420	0	0	420	3,800	2,800
7	403,947	1,087y	500,000y	y	y	y	36	25	0	0	36	0	0	36	4,421	4,299
8	103,044	354	y	y	y	y	4	3	0	0	4	0	0	4	6,200	5,950
9	63	0	x	x	x	x	6	0	6	0	0	0	0	0	1,600	1,599
10	424,140	952	x	x	x	x	62	1	1	0	40	0	0	40	2,550	2,450
11	753	23	x	x	x	x	2	1	0	0	2	0	0	2	5,038	4,970
12	2,039	y	x	x	y	x	1	1	0	0	1	0	0	1	5,100	y
13	114,737	211	x	x	x	x	15	0	0	3	12	0	0	12	4,200	3,900
14	2,914,430	7,037	x	x	x	x	y	77	y	y	181	y	0	181	4,400	3,950
15	828,562	3,500	x	x	x	x	85	75	y	y	77	y	y	77	4,310	4,100
16	3,304,957	11,115	x	x	y	x	363	332	0	0	360	228	3	363	4,250	4,175
17	263,269	888	x	x	x	x	22	19	0	0	22	0	0	22	4,280	4,090
18	15,082	41	x	x	x	x	1	0	0	0	0	0	0	1	4,166	4,100
19	2,827,540	6,518	y	y	y	y	226	52	0	1	223	0	2	225	3,600	3,450
20	0	0	0	0	0	0	1	0	0	1	0	0	0	0	4,850	4,796
21	26,692	160	y	0	y	y	4	4	1	0	4	0	0	4	5,029	4,988
22	189,973	1,852	x	x	x	x	21	21	0	y	21	0	0	21	5,000±	4,950±
23	16,622	28	x	x	x	x	8	0	0	2	6	0	0	8	2,600	2,510
24	647,072x	2,184	x	x	x	x	270	22	0	0	270	x	0	270	1,400	1,280
25	103,445x	394	x	x	x	x	59	1	y	0	59	0	0	59	1,750	1,650
26	550,785x	1,501	x	x	x	x	49	0	0	1	48	0	0	48	2,300	2,150
27	3,092,617x	8,963	x	x	x	x	265	16	0	0	265	0	0	265	2,600	2,500
28	1,380,430x	3,649	x	x	x	x	140	18	0	y	140	0	0	140	3,000	2,800
29	3,024	3,024	x	x	x	x	y	y	y	y	y	y	y	y	2,664	2,632
30	10,275	y	x	x	x	x	3	3	0	0	3	0	0	3	5,023	4,968
31	2,526,367	7,265	x	x	x	x	232	44	0	1	231	0	0	231	2,800	2,450
32	9,945	12	x	x	x	x	17	1	0	1	9	0	0	9	1,410	1,400
33	88,560	302	x	x	x	x	5	5	0	0	5	0	0	5	3,903	3,890
34	525,913	1,481	x	x	x	x	97	3	0	15	82	0	0	82	4,304	4,297
35	308,506	900	x	x	x	x	136	0	0	19	106	0	0	106	3,000	2,800
36	290,420	650	x	x	x	x	22	8	0	2	20	0	0	20	1,400	1,200
37	0	0	x	x	x	x	1	0	0	1	0	0	0	0	1,378	1,338
38	95,662	259	x	x	y	y	15	7	0	0	15	0	0	15	2,300	2,225
39	163,106	501	x	x	x	x	69	17	0	5	64	0	0	64	1,600	1,300
40	0	0	x	x	x	x	3	0	0	2	0	0	0	y	1,400	1,385
41	27,500y	75	x	x	x	x	10	1	1	1	9	0	0	9	1,016	970
42	387,335	1,050y	x	x	x	x	58	8	3	0	54	0	1	55	1,675	1,630
43	71,868	179	x	x	x	x	10	0	0	0	10	0	0	10	1,100	900
44	10,558,488	24,709	113,605	2,828	2,163	7.4	542	28	0	0	542	0	0	542	1,450	1,310
45	y	y	x	x	x	x	197	26	1	0	197	0	0	197	445	400
46	0	0	x	x	x	x	3	0	0	1	0	0	0	0	1,700	1,650

Wasson-Denver field. This field covers at this time approximately 20,000 acres and is not as yet fully outlined.

Slaughter Field.—Slaughter field, in Hockley County, was discovered in April 1937. An extension 3½ miles to the southeast by Stanolind's

TABLE 1.—(*Continued*)

	Oil Production Methods at End of 1937						Pressure, Lb. per Sq. In.^{d}			Character of Oil, Approx. Average during 1937					Character of Gas, Approx. Average during 1937	
	Number of Wells						Initial	Average at End of		Gravity A.P.I. at 60° F.						
Line Number	Flowing	Pumping	Gas-lift	Air-lift	Miscellaneous	Injection into Reservoir^c		1936	1937	Maximum	Minimum	Weighted Average	Sulphur, Per Cent	Base^e	B.t.u. per Cu. Ft.	Gal. Gasoline per M Cu. Ft.
1	22	10	0	0	0	0	*x*	*x*	*y*	31	24	28.1	*y*	M	*y*	*y*
2	0	0	0	0	0	0	*y*	*y*	*y*	29	30	29	*y*	*y*	*y*	*y*
3	33	1	18	0	0	0	1,900	1,657	1,512	*y*	*y*	31	*y*	M	603	*y*
4	0	2	0	0	0	0	*x*	*x*	*x*	31	28	29.5	*x*	M	*x*	*y*
5	2	0	0	1	0	0	1,100	1,100	1,100	31	30	30.6	1.7	M		
6	130	290	0	0	0	0	725	*y*	*y*	33	36	32	2.5	M	1,100	1.7
7	36	0	0	0	0	0	2,100	*x*	1,761	*y*	*y*	*y*	*y*	*y*	*y*	*y*
8	2	2	0	0	0	0	2,850	2,850	2,850	47	35	45		OM	*x*	*x*
9	0	0	0	0	0	0	*x*	*x*	*x*	19	19	19	1.5	M	1,097	0.15
10	0	40	0	0	0	0	*x*	*x*	*x*	30	28	29	0.7	M	*y*	*y*
11	0	2	0	0	0	0	*x*	*x*	*y*	*y*	*y*	31	*y*	A	*y*	*y*
12	0	1	0	0	0	0	*y*	*y*	*y*	*y*	*y*	37	*y*	*y*	*y*	*y*
13	5	7	0	0	0	0	*y*	*y*	*y*	19	19	19	1.15	M	1,097	0.15
14	170	16	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*
15	23	54	*y*	*y*	*y*	*y*	*y*	*y*	*y*	37	35	36	*x*	M	*x*	*x*
16	342	17	1	0	0	0	1,675	1,617	1,470	40	34	37	1.9	M	*y*	0.5
17	18	4	0	0	0	0	900	*y*	*y*	38	36	37	*x*	M	*y*	*y*
18	0	1	0	0	0	0	*x*	*y*	*y*	32.6	35.8	36	2.0	A	*y*	*y*
19	170	55	0	0	0	0	1,550	1,400±	1,350±	37	34	36	2.6	M	*y*	1.5
20	0	0	0	0	0	0	*x*	*x*	*x*	28	26	27	*y*	*y*	*x*	*x*
21	4	0	0	0	0	0	2,000±	*x*	2,000±	34	34	34	*y*	M	*y*	*y*
22	21	0	0	0	0	0	*y*	*y*	*y*	*y*	*y*	35	*y*	M	*y*	*y*
23	0	6	0	0	0	0	*x*	*x*	*x*	40	38	39	*y*	*y*	*y*	*y*
24	0	270	0	0	0	0	*x*	*x*	*x*	35	31	33	1.0	*x*	*x*	*x*
25	0	59	0	0	0	0	*x*	*x*	*x*	*x*	*x*	32	0.8	*y*	*x*	1.8
26	0	48	0	0	0	0	*x*	*x*	*x*	31	26.7	27	3.4	M	*x*	*x*
27	0	265	0	0	0	0	0	265	0	*y*	*y*	28	2.0	*y*	*x*	*x*
28	140	0	0	0	0	0	*x*	*x*	*x*	*x*	*x*	30	2.0	M	*x*	*x*
29	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*
30	2	1	0	0	0	0	*y*	*y*	*y*	32	32	32	*y*	M	*y*	*y*
31	16	215	0	0	0	0	*x*	*x*	*x*	*x*	*x*	27	2.0	M	*y*	*y*
32	0	9	0	0	0	0	*x*	*x*	*x*	*y*	*y*	39	*y*	*y*	*y*	*y*
33	5	0	0	0	0	0	*y*	*y*	*y*	*y*	*y*	38	*y*	*y*	*y*	*y*
34	73	5	4	0	0	0	1,650	900	750	59	31	38	0.2	M	1,000	1.0
35	0	106	0	0	0	0	1,000*x*	*y*	*y*	27	25	26	2.5	M	*y*	*y*
36	5	15	0	0	0	0	*x*	*x*	*x*	*y*	*y*	28	*y*	*y*	*y*	*y*
37	0	0	0	0	0	0	*x*	*x*	*x*	*x*	*x*	26	*y*	P	*x*	*x*
38	15	0	0	0	0	0	*x*	*x*	*y*	34	34	34	*y*	P	*x*	*x*
39	*y*	*y*	0	0	0	0	*x*	240±	*y*	37	23	31	1.0	P	1,000	*y*
40	0	2	0	0	0	0	*x*	*x*	*x*	24	24	24	0.6	A	*x*	*x*
41	0	9	0	0	0	0	*x*	*x*	*x*	30	24	28				
42	2	53	0	0	0	0	*x*	*x*	*x*	31	29	30	1.3	A	*x*	*x*
43	0	10	0	0	0	0	100	*x*	*y*	32	32	32	0.3	*y*	*y*	*y*
44	509	28	0	0	5	0	700*y*	536	535	31	29	30	1.6	M	*y*	0.8*y*
45	0	197	0	0	0	0	*x*	*x*	*x*	*y*	*y*	23	1.9	M	*y*	*y*
46	0	0	0	0	0	0	*x*	*x*	*x*	31	31	31	*y*	M	*x*	*x*

No. 1 Slaughter and a favorable showing in Sid Richardson's No. 1 Slaughter, about 2½ miles due north from the discovery well, suggest that Slaughter field will be of major proportions. Production in Slaughter field is from Permian limestone at about 5000 ft. The discovery well,

TABLE 1.—(*Continued*)

Line Number	Producing Rock						Number of Dry and/or Near-dry Holes to End of 1936	Deepest Zone Tested to End of 1937	
	Name	Age[f]	Character[g]	Porosity[h]	Net Thickness, Average in Feet	Structure[i]		Name	Depth of Hole, Ft.
1	Big lime	Per	D	Por	25[y]	A	4	Permian	5,088
2	Big lime	Per	DL	Por	y	A	y	Permian	4,342
3	Big lime	Per	DL	Cav	20	A	1	Permian	4,556
4	Big lime	Per	D	Por	5	MC	0	Permian	4,814
5									
6	Big Lake lime	Per	DL	15	75	A	3	Ordovician	12,786
7	Big lime	Per	D	Por	50	AD	6	Ordovician	6,450
8	Simpson-Ellenburger	Ord	LS	Por	20	AD	3	Cambrian	y
9	Big lime	Per	D	Por	10	A	0	Ordivician	8,041
10	Big lime	Per	DL	Por	13	AD	4	Ordovician	8,830
11	Big lime	Per	DL	Por	y	A	0	Permian	5,055
12	Delaware	Per	S	Por	y	A	y	Permian	5,100
13	Big lime	Per	DL	Por	10	A	0	Ordovician	8,041
14	Big Lake lime	Per	DL	Por	20	A	y	y	y
15	Big lime	Per	DL	Por	30±	A	4	Permian	4,517
16	Big lime	Per	DL	Por	40±	A	5	Permian	4,557
17	Big Lake lime	Per	D	Por	120	T	5	Big lime	4,518
18	Big lime	Per	DS	Por	30	A	0	Big lime	4,166
19	Big lime	Per	DL	Cav Por	40	A	14	Permian	4,002
20	Big lime	Per	DS	Por	50	A	0	Permian	4,870
21	Big lime	Per	DL	Por	60±	A	0	Permian	5,112
22	Big lime	Per	L	Por	y	A	5	Permian	5,097
23	Big lime	Per	SLs	Por	10	A	1	Permian	4,801
24	Yates sand	Per	Sand	Por	20	A	5	Ordovician	10,960
25	1700-ft. pay	Per	Ss	22	20	A	y	Ordovician	10,960
26	2200-ft. pay	Per	Ss	Por	x	A	10	Ordovician	10,960
27	2500-ft. pay	Per	L	Por	x	A	2	Ordovician	10,960
28	3000-ft. pay	Per	DL	Por	x	A	11	Ordovician	10,960
29	Big lime	Per	DL	Por	4	D	y	Permian	3,247
30	Big lime	Per	L	Por	55	A	0	Permian	5,032
31	Big lime	Per	DL	Por	50	A	12	Permian	4,220
32	Yates sand	Per	Ss	Por	10	M	y	Permian	3,511
33	Delaware sand	Per	Ss	y	y	y	4	Permian	3,972
34	Delaware sand	Per	Ss	Por	7	M	6	Delaware	5,083
35	Big lime	Per	DL	Por	50	MC	4	Pennsylvania	5,250
36	Pecos Valley sand	Per	Ss	Por	5	M	y	Permian	1,675
37	Yates sand	Per	Ss	Por	10	T	4	Permian	2,800
38	Yates sand	Per	Ss	Por	15	A	1	Permian	2,459
39	Pecos Valley sand	Per	Ss	Por	15	A	15	Permian	2,550
40	Yates sand	Per	SH	Por	25	A	7	Permian	4,375
41									
42	Permian	Per	DL	Por	15	A	y	Permian	2,185
43	Yates sand	Per	Ss	Por	15	AL	0	Permian	1,852
44	Yates lime	Per	DL	Por	100±	A	17	Permian	1,938
45	Tobarg sand	Cre	Ss	Por	20	AL	24	Permian	1,400
46	Big lime	Per	DS	x	10	A	10	Ordovician	9,811

The Texas Company's No. 1 Slaughter, logged 55 ft. of saturated limestone before encountering sulphur water at 5032 ft., and after a two-stage acid treatment totaling 8000 gal. showed an initial production of 520 bbl. per day. Without consideration of the almost certain extension to be made by the Richardson No. 1 Slaughter to the north, it may be conservatively assumed that about 2000 acres are already proven for production, and that a like amount will be added by the Richardson well if it becomes a producer.

Mason Field.—Michigan Oil and Gas Company's No. 2 Kyle opened a new Permian "Delaware" sand field in January 1937. Saturated sand section was found from 3895 to 3903 ft., and the discovery well flowed 347 bbl. per day of 38° gravity nonsulphur crude oil. Five wells were completed to the end of 1937 in Mason field, and production for the month of December was 7349 bbl., or 237 bbl. per day. Two dry holes, which

TABLE 1.—(*Continued*)

Line Number	*County*, Field	Age, Years to End of 1937	Area Proved, Acres				Total Oil Production, Bbl.	
			Oil	Oil and Gas[a]	Gas	Total	To End of 1937	During 1936
	Regan: Big. Lake,							
47	2400-ft. pay[6]	14	275	0	0	275	*x*	*x*
48	3000-ft. pay	14	3,000	0	0	3,000	62,161,589	1,931,503
49	Ordovician	9	1,300	0	0	1,300	25,698,390	1,095,899
50	Grayson	9	640	0	0	640	518,771	59,486
51	*Reeves:* Toyah	18	640 ±	0	0	640±	6,500±	0
52	*Scurry:* Ira-Northwest	13	640	0	0	640	113,114	12,199
53	*Upton-Crane:* McCamey-Hurdle		*y*	0	0	*y*	38,740,709	5,209,238
54	Cordova-Union	2	160	160	0	160	23,163	14,370
55	*Ward:* Dobbs		40	0	0	40	10,603	6,924
56	Estes	2	4,500	0	0	4,500	3,362,918	309,063
57	Monroe		*y*	*y*	*y*	*y*	26,280	9,155
58	North Ward	*x*	*x*	*x*	*x*	*x*	*x*	2,951,948
59	South Ward	8	10,000	0	0	10,000	*x*	5,083,173
60	Shipley	8	2,500	0	0	2,500	*x*	597,252
61	Ward Co.[7]	9	35,000	*x*	1,000	36,000	37,346,883	8,957,515
62	*Winkler:* Bashara		160	0	0	160	26,228	10,361
63	Emperor	2	1,400	0	160	1,560	821,589	280,695
64	Halley		800±	0	0	800	*y*	72,942
65	Hendrick	11	9,200	0	0	9,200	*y*	4,791,768
66	Henderson	2	2,600	0	0	2,600	e1,548,309	193,126
67	Kermit	9	18,260	*x*	*x*	18,260	e12,006,001	*x*
68	Keystone-Walton	2	*y*	*y*	*y*	*y*	1,644,962	483,481
69	Leck	10	960	0	0	960	3,321,718	161,361
70	Scarbrough	11	1,160	0	0	1,160	3,238,964	649,782
71	Sealey[8]		*y*	*y*	*y*	*y*	*y*	177,666
72	*Yoakum:* Bennett	1	980	0	0	980	123,462	9,505
73	Bohago-Bond	0	*y*	*y*	*y*	*y*	*y*	*y*

[6] Production figures included under "3000-ft pay."
[7] Includes Sealey production, Winkler County.
[8] Included under Ward County for production figures.

offset the discovery well, defined the field to the south, while a small pumping well completed 2 miles due west from the discovery well and a dry hole 2 miles due east indicate that any expansion of the productive acreage of the Mason field will be due north from the discovery.

Other Discoveries.—Emma field, in southern Andrews County; Scanlan field, Dawson County; Bohago-Bond field, Yoakum County and Herrington field, Upton County, were also added to the list of new West Texas fields during 1937. The magnitude of these new fields is as yet unknown and will be better determined by subsequent drilling operations.

EXTENSIONS TO OLDER FIELDS

Ector County was most favored in extensions to its older producing fields. Goldsmith field was broadened about a mile on each side and had its length increased about a mile or more on each end through rapid

TABLE 1.—(*Continued*)

	Total Oil Production, Bbl.		Total Gas Production, Millions Cu. Ft.				Number of Oil and/or Gas Wells								Depth, Average in Feet	
								During 1937		At End of 1937						
Line Number	During 1937	Daily Average during Nov. 1937	To End of 1937	During 1936	During 1937	Maximum Daily during 1937	Completed to End of 1937	Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Oil and Gas^b	Producing Gas Only	Total Producing	Bottoms of Productive Wells	To Top of Productive Zone
47	*y*	*x*	*x*	*x*	*x*	*x*	21	0	*y*	*y*	*y*	0	0	*y*	2,500	2,375
48	1,725,535	5,138	*x*	*x*	*x*	*x*	261	0	3	*x*	198	0	0	198	3,000	2,960
49	998,995	2,463	*x*	*x*	1,849	*x*	24	0	7	1	10	6	*x*	16	8,900	8,200
50	58,726	156	*x*	*x*	*y*	*y*	5	0	0	0	5	0	0	5	3,100	3,050
51	0	0	*x*	*x*	*x*	*x*	35	0	*y*	*y*	0	0	0	0	100	100
52	12,930	31	*x*	*x*	*x*	*x*	10	1	0	0	10	0	0	10	2,395	2,320
53	6,663,062	18,310	*x*	*x*	*x*	*x*	835	285	15	0	820	0	0	820	3,000	2,800
54	8,204	24	*x*	*x*	*x*	*x*	3	1	0	0	3	0	0	3	2,150	2,060
55	3,679	9	*x*	*x*	*x*	*x*	2	0	0	0	2	0	0	2	2,570	2,555
56	3,053,855	6,859	*x*	*x*	*y*	*y*	232	176	0	0	0	232	1	232	2,950	2,450
57	8,850	25	*x*	*x*	*x*	*x*	1	0	0	0	1	0	0	1	4,675	4,665
58	*y*	*y*	*x*	*x*	*x*	*x*	*x*	*x*	*x*	*x*	*x*	*x*	*x*	*x*	3,600	3,300
59	5,570,509	12,205	*x*	*y*	*y*	*y*	659	102	0	0	0	657	2	659	2,525	2,350
60	609,211	*y*	*x*	*x*	*x*	*x*	96	15	0	0	96	0	0	96	3,100	3,075
61	12,195,967	28,124	*x*	*x*	*x*	*x*	1,270	436	5	*y*	1,253	*y*	12	1,265	2,700	2,500
62	15,867	84	*x*	*x*	*y*	*y*	6	2	0	0	5	0	1	6	3,450	3,350
63	508,504	1,386	*x*	*x*	*y*	*x*	56	27	0	0	54	0	2	55	3,100	2,833
64	208,803	605	*x*	*y*	*y*	*y*	24	14	0	0	23	0	1	24	3,200	3,100
65	*y*	*y*	*x*	*x*	*x*	*x*	629	4	*y*	*y*	376	*y*	*y*	376	2,900	2,600
66	1,355,183	e3,135	e1,625,000	*x*	*x*	*x*	113	70	0	0	112	0	1	113	3,075	3,025
67	6,644,220	e17,767	e17,160,000	*y*	*y*	*y*	787	414	0	0	772	0	15	787	3,053	2,817
68	1,062,458	2,750	*x*	*x*	*y*	*y*	73	42	0	0	73	0	0	73	3,600	3,000
69	176,961	481	*x*	*x*	*x*	*x*	16	0	*y*	0	9	*x*	0	9	3,100	3,000
70	442,569	1,212	*x*	*x*	*x*	*x*	97	8	0	0	97	0	0	97	3,400	2,860
71	*y*	*y*	*x*	*x*	*x*	*x*	21	6	0	0	21	0	0	21	3,200	3,100
72	113,957	*y*	0	0	0	0	5	4	0	0	0	5	0	5	5,260	5,050
73	*y*	*y*	*y*	*y*	*y*	*y*	1	1	0	0	0	0	0	1	5,225	*y*

but orderly drilling. The field now includes a total of approximately 15,000 acres, exclusive of the Scharbauer area, which roughly covers 6500 acres, or a total of about 21,500 acres. There were 348 flowing and 12 pumping wells in the Goldsmith field with a total daily production of 11,493 bbl., or an average of 31.93 bbl. per day per well. Of the total number of producers, 26 wells were showing from 1 to 40 per cent water in December of 1937.

Harper field was extended 2 miles due northwest, and in its formerly proven portion large flowing wells were drilled, resulting in very active development of its older area as well as of the northwest extension. Foster and North Cowden fields both received minor extensions during 1937, while the formerly proven acreage in these two fields was actively developed. Active development in Winkler, Crane, Upton, Ward and other counties added considerably to the reserves and to the proven acreage.

TABLE 1.—(*Continued*)

	Oil Production Methods at End of 1937						Pressure, Lb. per Sq. In.[d]			Character of Oil, Approx. Average during 1937					Character of Gas, Approx. Average during 1937	
	Number of Wells							Average at End of		Gravity A.P.I. at 60° F.						
Line Number	Flowing	Pumping	Gas-lift	Air-lift	Miscellaneous	Injection into Reservoir[e]	Initial	1936	1937	Maximum	Minimum	Weighted Average	Sulphur, Per Cent	Base[e]	B.t.u. per Cu. Ft.	Gal. Gasoline per M Cu. Ft.
47	0	*y*	0	0	0	0	*x*	*x*	*x*	*y*	*y*	35	0.3	*y*	*x*	*x*
48	0	198	0	0	0	0	*x*	*x*	*x*	*y*	*y*	36	0.4	M	*y*	*y*
49	12	0	4	0	0	0	3,600	*x*	*x*	74.9	41	44	0.2	P	1,200	1.17
50	0	5	0	0	0	0	*x*	*x*	*x*	33	31	32	1.0	M	*x*	*x*
51	0	0	0	0	0	0	*x*	0	0	*y*	*y*	27	1.7	M	*x*	*x*
52	0	10	0	0	0	0	*x*	*x*	*x*	25	25	25	2.1	M	*y*	*y*
53	0	820	0	0	0	0	*x*	*x*	*x*	*y*	*y*	28	2.0	M	*x*	*x*
54	0	3	0	0	0	0	*x*	*x*	*x*	25	25	25	*y*	M	*x*	*x*
55	0	2	0	0	0	0	*x*	*x*	*x*	*y*	*y*	*y*	*y*	M	*y*	*y*
56	232	0	0	0	0	0	*x*	*y*	1,100	*y*	*y*	36	*y*	*y*	*y*	*y*
57	1	0	0	0	0	0	*x*	*x*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*
58	739	78	*x*	*x*	*x*	*x*	e1,400	e700	*y*	38	31	36	1.2	P	1,129	1.2
59	600*y*	50*y*	7*y*	0	0	0	1,300	*y*	500	*y*	*y*	34	*y*	M	*y*	1.0
60	36	60	0	0	0	0	*x*	*y*	*y*	*y*	*y*	32	*y*	M	*y*	*y*
61	*y*	*y*	0	0	0	0	1,400	1,000	900	38	31	36	1.2	P	1,129	1.2
62	4	2	0	0	0	0	*x*	*x*	*y*	*x*	*x*	28.5	*y*	*y*	*x*	*x*
63	48	6	0	0	0	0	e1,300	*x*	*x*	35.5	32	33	*y*	M	*y*	*y*
64	17	70	0	0	0	0	*x*	*x*	*y*	*y*	*y*	36	*y*	*y*	*x*	*x*
65	109	267	*y*	*y*	*y*	*y*	e1,600±	*x*	*x*	35	24	28	1.5	M	*y*	*y*
66	112	0	0	0	0	0	1,450	1,321	1,308	30	27	*x*	*y*	*y*	*y*	*y*
67	749	17	6	0	0	0	1,450	*x*	931	37	32	*x*	*y*	*y*	*y*	*y*
68	70	3	0	0	0	0	e2,000+	e,2000+	*y*	38	36	37	1.5	M	*y*	*y*
69	0	9	0	0	0	0	*y*	100	100	*x*	*x*	28.1	1.6	M	*x*	*x*
70	69	28	0	0	0	0	1,200+	*y*	*y*	35.4	34.6	35.0	1.4	M	1,100	1.0
71	16	5	0	0	0	0	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*
72	5	0	0	0	1 FC	0	1,100e	1,000	1,000	34	32	33	*x*	M	*x*	0.864
73	1	0	0	0	1	0	*y*	*y*	*y*	*y*	*y*	31	*y*	*y*	*x*	*x*

Jordan field, first considered by many as a separate field, now appears to be a connecting link between the Penwell (Judkins) field and the Waddell field; and is developing into an extension of major importance, owing to an active drilling campaign early in 1938.

Kermit field, Winkler County, became a separate entity on March 1, 1937, through the consolidation of Brown-Altman, Keyes and Sayre fields. On Jan. 1, 1937, Brown-Altman had 54 oil wells and a daily allowable of 2165 bbl.; Keyes, 118 oil wells and a daily allowable of 5664 bbl., and Sayre, 213 oil wells with a daily allowable of 8310 bbl. The result of an active, 10-acre spacing, drilling campaign in Kermit field has been reflected in the addition of 433 oil wells to the 356 wells producing on Jan. 1, 1937, the total, on Jan. 1, 1938, reaching 789. Daily production also increased from 11,506 bbl. on Jan. 1, 1937 to 17,887 bbl. on Jan. 1, 1938. The large increase of new oil wells completed had the effect of lowering the daily average production per well from 32.32 bbl. on Jan. 1, 1937 to 22.67 bbl. on Jan. 1, 1938.

TABLE 1.—(*Continued*)

Line Number	Producing Rock						Number of Dry and/or Near-dry Holes to End of 1937	Deepest Zone Tested to End of 1937	
	Name	Age[f]	Character[g]	Porosity[h]	Net Thickness, Average	Structure[i]		Name	Depth of Hole, Ft.
47	Big lime	Per	Ss	20%	x	AD	10	Lower Ordovician	9,562
48	Big Lake lime	Per	DL	Por	30	AD	10	Lower Ordovician	9,562
49	Ellenberger	Pen	L	Por		D	2	Lower Ordovician	9,562
50	Big lime	Per	DL	Por	y	D	1	Mis	9,967
51	Big lime	y	y	y	y	MC		Pennsylvanian	5,250
52	Big lime	Per	DC	Por	25	A	7	Permian	4,528
53	Big Lake lime	Per	DL	Cav	30	A	61	Permian	4,610
54	Big lime	Per	DL	Por	y	A	1	Permian	2,125
55	Shipley-Hazlett	Per	Ss	Per	6	y	3	Permian	2,600±
56	Estes sand	Per	Ss	Por	15	A	0	Permian	3,000
57	Delaware sand	Per	S	Por	4	T	y	Permian	4,675
58	y	Per	S	Por	y	y	y	Permian	y
59	Penn-Bennett	Per	S	Por	30	A	6	Permian	3,000±
60	Shipley-Big lime	Per	S-DL	Por	10	A	y	Permian	4,400±
61	O'Brien sand	Per	S	Por	50	ML	y	Permian	4,825
62	Big lime	Per	DL	Por	5	A	y	Permian	y
63	O'Brien sand	Per	Ss	Por	40	AC	0	Permian	y
64	Big lime	Per	DL	Por	5	A	1	Permian	y
65	Big lime	Per	D	Por	x	A	26y	Permian	y
66	Big lime	Per	DL	Cav	30	A	3	Permian	y
67	Big lime	Per	DL	Por	10±	A	4	Permian	y
68	Big lime Yates sand	Per	LS	Por	30±	AD	3	Permian	4,463
69	Big lime	Per	DL	Cav	200	A	5	Permian	3,780
70	O'Brien sand	Per	Ss	Por	35	D	3	Permian	3,565
71	Big lime	Per	DL	Por	10	A	y	Permian	y
72	Big lime Blaine	Per	D	Por	130	MC	0	Permian	5,279
73	Big lime Blaine	Per	L	Por	y	y	y	Permian	5,255

ORDOVICIAN

More than a dozen wildcat wells were drilled in search of Ordovician production during 1937 in the West Texas Permian Basin. Gulf Production Co. completed two Ordovician wells in Sand Hills-Tubbs field, Crane County, and abandoned two deep Ordovician tests as dry holes. A well in northern Pecos County, near Imperial, being drilled by Magnolia Petroleum Co. gave promise of a new Ordovician producing area at the end of 1937, but it has not been completed as yet.

PRICES FOR CRUDE OIL

Prices for crude oil in West Texas were revised upwards on Jan. 28, 1937. Previously a price of $0.75 had been set for gravities below 29°, with $0.90 for 36° gravity and above and a per-degree differential of $0.02 from $0.76 for 29.0° to 29.9° gravity to $0.90 for 36° gravity and above. The new posted price quoted 25.0° to 25.9° gravity or lower at $0.78 with a per-degree differential of $0.02 to a top of $1.08 for 40° and above. One new purchaser varied slightly from the above by offering a flat quotation of $1.00 for 36° gravity and above but conforming otherwise with the other schedule.

CONCLUSIONS

Very rapid development of several older West Texas oil fields and the progressive extension of the Permian Basin producing territory to the

TABLE 2.—*Well Completions, Initial Production and Drilling Activity, West Texas District* 1936 *and* 1937[a]

Month	Completions of New Oil Wells		Initial Production, Thousands of Barrels		Dry Holes Drilled		Gas Wells Completed		Rigs, Up and Drilling	
	1937	1936	1937	1936	1937	1936	1937	1936	1937	1936
Jan.	166	85	128	38.9	19	18	1	4	426	283
Feb.	159	63	133.8	37.4	19	10	2	2	462	301
Mar.	234	92	235.3	50.6	30	14	2	2	546	295
Apr.	193	118	169.5	75.9	22	20	0	1	513	339
May	229	102	190.6	56.8	18	16	0	2	608	368
June	228	108	186.4	70.5	19	20	0	1	599	381
July	279	146	212.8	124.5	41	14	1	0	544	393
Aug.	205	115	150.3	66.0	37	16	2	4	522	373
Sept.	203	131	148.6	97.9	29	23	0	1	521	409
Oct.	188	142	157.4	96.7	30	19	2	3	490	435
Nov.	174	137	153.3	108.8	22	14	0	3	475	355
Dec.	206	128	150.3	91.2	45	10	1	2	449	436
Total	2,464	1,367	2,016.3	915.2	331	194	11	25		

[a] *The Oil and Gas Journal.*

north were the two outstanding features of 1937. The rapid development of such fields as Goldsmith, Kermit, Foster and others added some 2464 producing oil wells to the West Texas district, or a remarkable net increase of 42.58 per cent in the total number of producing oil wells in the district. During the year production from West Texas increased, however, only 22.09 per cent, resulting, as already indicated, in a 20.84 per cent decline in the average daily production per well. Assuming that during 1938 some 2500 oil wells will be again completed in West Texas, as appears probable, and that the annual production of this district will remain at about 75,000,000 bbl., the average daily allowable per well in West Texas will decline to about 20 bbl. by the end of 1938, as compared with 25.18 bbl. in December of 1937, or a further impressive drop of some 20.57 per cent. Hence it is evident that some limitations of the drilling development in West Texas is imperative during 1938 and 1939 if the daily well allowables are to be kept above the economic marginal limit, more particularly in view of limited market outlets for West Texas crude oil, both because of distance and grade. Wider spacing of wells in proven fields appears at this time the best way to change the present trend of the rapidly declining per-well per-day production in West Texas. The reserves of West Texas district were greatly augmented in 1937, both in actually proven fields and because of the north extension of the Basin, but while such increase in reserves can be considered as a constructive development, it can become so unwieldy by virtue of over drilling as to bring about economically destructive rather than constructive forces.

Acknowledgments

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Oil and Gas Development in Utah in 1937

By C. E. Shoenfelt,* Member A.I.M.E.

Wildcat drilling operations in Utah in 1937 added nothing of importance to the commercial oil and gas possibilities of the state, and such operations consisted largely of efforts to reach objectives in wells started in former years.

The Standard Oil Company of California, jointly with the Continental Oil Co., completed a wildcat well in sec. 22, 23 S., 11 E., on the San Rafael swell in Emery County, which was abandoned in metamorphic rocks at 4900 ft.; it tested the Pennsylvanian and Mississippian sections and probably ended in Devonian or older rocks.

The Utah Southern Oil Company's test of the Cisco structure in sec. 33, 22 S., 22 E., was abandoned at 6715 ft.; it may have been through the Pennsylvanian section at this depth.

The Mountain Fuel Supply Co. continued the development of its Clay Basin gas field, and with the completion of two wells in 1937 added 35,571,000 cu. ft. initial daily gas capacity to its reserves. This company constructed 21 miles of 10-in. gas pipe line from the Clay Basin field to its South Baxter Basin terminal in Wyoming, and during the closing months of 1937 delivered 2,225,000,000 cu. ft. of gas through the Salt Lake trunk line.

Table 1.—*Oil and Gas Production in Utah in 1937*

Line Number	Field, *County*	Age, Years to End of 1937	Area Proved, Acres			Total Oil Production, Bbl.			Total Gas Production, Millions Cu. Ft.		
			Oil	Gas	Total	To End of 1937	During 1936	During 1937	To End of 1937	During 1936	During 1937
1	Ashley Valley, *Uinta*	12		240	240				1,570.0	515	500
2	Cisco, *Grand*	13		2,000	2,000				3,128.0	0	0
3	Clay Basin, *Daggett*	10		2,800	2,800				2,121.5	0	2,121.5
4	Farnham, *Carbon*	14		600	600				1,482.0	368	44.5
5	San Juan, *San Juan*	28	160		160	11,000	0	0			
6	Virgin, *Washington*	30	450		450	159,250	3,000	2,250			
7	Total		610	5,640	6,250	170,250	3,000	2,250	8,301.5	883	2,216.0

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TABLE 1.—(*Continued*)

Line Number	Number of Oil and/or Gas Wells: Completed to End of 1937	During 1937: Completed	During 1937: Abandoned	At End of 1937: Temporarily Shut Down	At End of 1937: Producing Oil Only	At End of 1937: Producing Gas Only	At End of 1937: Total Producing	Depth, Average in Feet: Bottoms of Productive Wells	Depth, Average in Feet: To Top of Productive Zone	Oil Production Methods at End of 1937: Number of Wells Pumping	Pressure, Lb. per Sq. In.[d]: Initial	Pressure: Average at End of 1936	Pressure: Average at End of 1937	Character of Oil, Approx. Average during 1937: Gravity A.P.I. at 60° F.: Maximum	Gravity: Minimum	Gravity: Weighted Average	Base[e]
1	5	0	0			2	2	1,675	1,665		580	200	200				
2	13	0	13			0	0	2,174	2,056		750	600	580				
3	6	2	0			5	5	5,800	5,700		2,250	2,250	2,250				
4	2	0	0			1	1	3,114	3,093		750	325	320				
5	129	0	0				0	200	194					40	39	39	M
6	75	0	0	16	14		14	665	663	14				38	24	34	P
7	230	2	13	16	14	8	24			14							

[d] Footnotes to column heads and explanation of symbols are given on page 313.

Line Number	Character of Gas. Approx. Average during 1937: B.t.u. per Cu. Ft.	Producing Rock: Name	Producing Rock: Age[f]	Producing Rock: Character[g]	Producing Rock: Porosity[h]	Producing Rock: Net Thickness, Average in Feet	Producing Rock: Strucutre[i]	Number of Dry and/or Near-dry Holes to End of 1937	Deepest Zone Tested to End of 1937: Name	Deepest Zone Tested to End of 1937: Depth of Hole, Ft.
1	980	Morrison	Jur	S	*y*	10	AF	3	Nugget-Jur	2,720
2	1,080	Dakota Morrison	CreU Jur	S	*y*	15	D	3	Kayenta-Jur	3,045
3	1,100	Dakota	CreU	S	18	40	D	0	Sundance-Jur	6,790
4	CO_2	Coconino	Per	S	*y*	21	AF	1	Kaibab-Per	3,235
5		Goodridge	Pen	S	*y*	6	S	116	Hermosa-Pen	3,663
6		Kaibab-Moenkopi Cont. or upper Kaibab	Tr	L	*y*	2	MC	75	Coconino-Supai-Per	2,195
7								198		

TABLE 2.—*Summary of Drilling Operations in Utah*

	Proven Fields	Wild-cats
Number of wells drilling Dec. 31, 1937	0	4
Number of oil wells completed during 1937	0	0
Number of gas wells completed during 1937	2	0
Number of dry holes completed in 1937	0	3

Oil and Gas Development in West Virginia during 1937

By David B. Reger,[*] Member A.I.M.E.

(New York Meeting, February, 1938)

Extensive drilling for gas and increased pipe-line building were the major petroleum activities in West Virginia during 1937. According to the West Virginia Department of Mines, 1034 permits to drill were issued. A running account of operations from trade journals and other reports shows that 1041 wells were drilled, resulting in 193 oil wells with 1238 bbl. of daily production; 680 gas wells with 1,048,057,000 cu. ft. of daily open flow; and 168 dry holes. The new oil-well average is 6.4 bbl. per well per day; the gas-well average is 1,541,260 cu. ft. per well per day; the ratio of dry holes to completions is 16.13 per cent.

Very little attempt was made to develop new supplies of oil. Because of the continued low price, operators evidently considered it good business to leave oil in the ground rather than to produce it at a loss or on a small profit basis. The principal oil wells completed, by counties, are: Calhoun, 16; Clay, 10; Pleasants, 17; Ritchie, 42; Roane, 16; Tyler, 13; Wetzel, 11; Wirt, 14; Wood, 13.

The leading counties in gas, with the number of successful wells in each, are: Boone, 54; Braxton, 31; Cabell, 48; Calhoun, 46; Gilmer, 82; Kanawha, 134; Lincoln, 44; Ritchie, 56; and Wayne, 26.

General State of the Industry

In Table 1 will be found an approximate summary of oil and gas territory and reserves, oil and gas production and number of oil and gas wells. The amount of land under lease is an approximation, because the exact figures are not available through any public or private agency. The proved land and reserves represent the opinion of the writer. The oil production for 1937 is subject to revision, and the gas production for the same year is only an estimate, based on demand and supply. The number of oil and gas wells now active is also an approximation, based on previous studies, and revised for completions and abandonments.

Principal Areas of Activity

In Boone County, 62 wells were drilled in various localities, resulting in 4 oil wells and 54 gas wells with 18,170,000 cu. ft. of new production.

Summary received at the office of the Institute Jan. 27, 1938; entire paper, March 15, 1938.

[*] Consulting Geologist, Morgantown, W. Va.

This gas was mainly in old sands, but one new Oriskany sand (L. Dev.) well, with 300,000 cu. ft. of open flow and 1230 lb. rock pressure, is reported from Peytona District. Heretofore, other wells drilled to the Oriskany in this county have been dry.

In Braxton County there was a considerable revival of gas activity, resulting in 31 productive wells, with 12,041,000 cu. ft. of new production.

TABLE 1.—*Oil and Gas Territory, Reserves, Production, and Wells in West Virginia as of Dec.* 31, 1937

OIL AND GAS TERRITORY AND RESERVES

Held by Leases, Probable and Improbable Territory, Acres	Probable Territory Not Held by Leases, Acres	Proved and Probable Acres		Reserves	
		Oil	Gas	Oil, Bbl.	Gas, Millions Cu. Ft.
5,000,000	250,000	750,000	2,500,000	93,000,000	7,000,000

OIL AND GAS PRODUCTION

Period	Oil, Bbl.	Average Oil per Well Daily, Bbl.	Gas, Millions Cu. Ft.	Average Gas per Well per Day, Cu. Ft.
To end of 1937	402,892,000		6,205,400	
During 1936	3,847,000[1]	0.56	139,102[2]	29,543
During 1937	3,800,000[3]	0.56	150,000[3]	30,992

NUMBER OF OIL AND/OR GAS WELLS

Number Completed to End of 1937, Oil and Gas	Number Completed during 1937		Number at end of 1937	
	Oil	Gas	Oil	Gas
62,073 ±	193	680	18,575 ±	13,260 ±

[1] Figures by U. S. Bureau of Mines.

[2] Figures by Public Service Commission of West Virginia.

[3] Estimated.

Cabell County shows the remarkable record of 48 gas wells out of 49 completions and only one dry hole. There was no oil but the new gas wells totaled 17,863,000 cu. ft. of open flow.

In Calhoun County a considerable amount of routine drilling was done, yielding 16 oil wells with 184 bbl., and 46 gas wells with 38,366,000 cubic feet.

In Gilmer County, the Glenville gas pool was the principal new discovery of the year. This territory, in or closely adjacent to the town of Glenville, where some unsuccessful drilling had been done in earlier years, was opened by the completion of a 5,600,000-cu. ft. well in the Maxton sand (U. Mis.) in January. The intensive drilling that followed resulted in 42 gas wells out of 47 wells drilled, with 43,612,000 cu. ft. of new production. Contrary to the discovery well, most of this production is in the Big Injun sand (L. Mis.), with scattered wells in the Salt (basal Pen.), Big Lime and Keener (L. Mis.). This pool is on the Chestnut Ridge anticline, which is generally productive elsewhere in Gilmer County. Well depths to the Big Injun sand at Glenville average about 1700 ft. All the other productive sands are nearer the surface. No definite outside limit of production is yet indicated, but it is probable that the pool will connect with other producing territory to the northeast and southwest.

In Kanawha County the dominant activity has been the drilling for gas in the Oriskany sand (L. Dev.) and the laying of new pipe lines, both of which will be hereinafter detailed.

In Lincoln County there were 8 oil wells with 104 bbl. of new production; 44 gas wells with 25,680,000 cu. ft. of open flow, and only one dry hole. A considerable part of the new gas represents deeper drilling of old wells down to the brown shale, or Childres sand (M. Dev.).

Ritchie County had 127 completions, resulting in 42 oil wells with 249 bbl., 56 gas wells with 17,357,000 cu. ft., and 29 dry holes.

In Roane County, 16 oil wells yielded 152 bbl. and 16 gas wells measured 15,147,000 cubic feet.

Wayne County had one small oil well, 26 gas wells measuring 17,010,000 cu. ft., and one dry hole.

Wetzel County records 11 oil wells with 79 bbl., 19 gas wells with 23,779,000 cu. ft., and 9 dry holes.

In Wirt County several wells drilled to the Oriskany sand were failures, but some oil was found in an Upper Devonian sand that has not heretofore been productive in that county. This new sand is not accurately identified, but may be near the Elizabeth horizon.

Development in Oriskany Sand

Late in the year 1934 the completion of a fairly good oil well in the Oriskany sand (L. Dev.) in Kanawha County led to the hope that a valuable pool might have been discovered. The large exploration campaign that followed dissipated the prospect of oil but revealed immense quantities of gas. The successful development to date is principally confined to Kanawha County. By the end of 1936 there had been 64 successful wells, with 230,912,000 cu. ft. of daily open flow. In 1937 there were 100 successful completions, with 691,954,000 cu. ft. of open flow, making a grand total of 922,866,000 cu. ft. Altogether, 184 wells have been drilled with only 20 dry holes. The average open flow per gas well has been 5,627,232 cu. ft., with rock pressures that vary from 1200 to 2000 lb. In

January 1938, there were 113 wells listed as drilling but several of these, for various reasons, may never be completed.

This development originated on the northwestern slope of the Warfield (Chestnut Ridge) anticline and almost coincidently on the Milliken anticline, which starts slightly north of the Warfield and extends northward into Roane County. The greatest activity at present is in Poca and Union districts, west of the Milliken anticline, where several large wells are reported weekly.

The definitely proved territory principally consists of three areas. The first of these, which has been described as the Campbell-Davis Creek pool, is on the Warfield anticline in Malden and Loudon districts southeast of Charleston. The second, known as the Cooper Creek pool, is at or near the southern end of the Milliken anticline in Elk district northeast of Charleston. The third, known as the Elk-Poca pool, is on the axis and western slope of the Milliken anticline in Elk, Poca and Union districts, principally north of Charleston. As of Jan. 1, 1938, there were approximately 50,000 acres of proved territory in the three pools. Unit production is not definitely known but it should be at least 5,000,000 cu. ft. per acre, or at least 250,000,000,000 cu. ft. for the proved territory. In January and February of 1938, at least 10,000 additional proved acres were added in Poca and Union districts.

In addition to the gas, a considerable amount of gasoline is recovered from these Oriskany wells. The maximum, when the wells are new and operating at the highest pressures, is about 700 gal. per million cubic feet of gas. With declining rock pressure, or with the use of the bottom-hole choke, less gasoline is recovered, so that the general average may be only 300 to 500 gal. per million cubic feet.

In other counties, the exploration for gas and oil in the Oriskany sand has shown indifferent results. In Peytona district, Boone County, an Oriskany well with 300,000 cu. ft. of open flow and 1230 lb. of rock pressure (15-hr. test) was completed in 1937. Various others in the same county, drilled in 1937 or previously, have been dry. In Jackson, Lincoln, Putnam and Roane Counties, all of which adjoin Kanawha, various Oriskany tests have now been drilled, resulting in dry holes or salt water. In Wirt County, farther north, two Oriskany tests on the Burning Springs anticline went to salt water after making only slight shows of oil or gas. In Wood County another test, considerably west of the Burning Springs anticline, showed 6 bbl. of oil and a little gas, but has been, or will be, abandoned. In Hancock County, at the extreme northern panhandle of the state, a completion in 1937 showed only a slight amount of oil, followed by salt water. In Wayne County a test (Oliver Viers No. 1 by Chartiers Oil Co.), which went deeper than the Oriskany horizon, measured 300,000 cu. ft. of open flow in the Newburg (Sil.) sand. The same company has two or three other Newburg wells in this county.

TABLE 2.—*Important Wildcats Drilled in West Virginia during* 1937

No.	County	Magisterial District	Location		Total Depth, Ft.	Surface Formation	Deepest Horizon Tested	Drilled by	Property and Well No.	Initial Production per Day		Tubing Pressure, Lb. per Sq. In.	Remarks
			Lat.	Long.						Oil, Bbl.	Gas, M Cu. Ft.		
1	Boone.....	Peytona	2.1 miles S. of 38° 15′	4.31 miles W. of 81° 35′	4,629	Pen.-Kanawha	L. Dev.-Oriskany	Owens, Libbey-Owens Gas Dept.	Bull Creek Land Co., 464	0	300	1,230	Oriskany gas
2	Boone.....	Sherman	4.9 miles S. of 38° 10′	0.14 mile W. of 81° 40′	5,299	Pen.-Kanawha	L. Dev.-Oriskany	Owens, Libbey-Owens Gas Dept.	Peytona Coal Land Co., 475	0	0	0	Dry in Oriskany. Brown shale gas, 105 M cu. ft.
3	Calhoun...	Center	5.2 miles N. of 38° 50′	0.8 mile E. of 81° 10′	6,225	Perm.-Dunkard	L. Dev.-Oriskany	Godfrey L. Cabot, Inc.	A. Hardman, 8-869	0	0	0	Little salt water in Oriskany; abandoned
4	Hancock...	Grant	5.6 miles N. of 40° 30′	4.0 mile E. of 80° 40′	5,015	Pen.-Conemaugh	L. Dev.-Oriskany	John T. Galey	R. Talbot, 1	0	0	0	Oil show and little salt water in Oriskany; abandoned
5	Jackson....	Washington	3.77 miles S. of 38° 45′	2.3 miles W. of 81° 30′	5.507	Perm.-Dunkard	L. Dev.-Oriskany	United Carbon Co.	E. W. Perkins, 1-701	0	0	0	Salt water in Oriskany; abandoned
6	Jackson....	Washington	0.5 mile S. of 38° 40′	2.7 miles W. of 81° 30′	5.462	Perm.-Dunkard	L. Dev.-Oriskany	United Carbon Co.	E. W. Perkins, 2-702	0	0	0	Salt water in Oriskany; abandoned
7	Kanawha..	Cabin Creek	0.17 mile N. of 38° 10′	0.15 mile W. of 81° 30′	5,193	Pen.-Kanawha	L. Dev.-Oriskany	Pure Oil Co.	Slaughter Cr. C. & L. Co., 6	0	0	0	Dry in Oriskany
8	Lincoln....	Jefferson	2.8 miles S. of 38° 10′	1.6 miles W. of 82° 00′	4,252	Pen.-Kanawha	L. Dev.-Oriskany	Kanawha Gas Utilities Co.	Spencer Hill, 203	0	31	372	Berea and shale gas. Tools stuck in Oriskany
9	Mason.....	Hannan	2.93 miles N. of 38° 30′	1.70 miles W. of 82° 05′	3,861	Pen.-Monongahela	L. Dev.-Oriskany	J. C. Blair et al.	Velma K. Hiner, 1	0	0	0	Dry, no Oriskany sand
10	Putnam....	Pocatalico	1.57 miles S. of 38° 30′	0.6 mile W. of 81° 45′	4,632	Pen.-Conemaugh	L. Dev.-Oriskany	West Virginia Gas Corp.	C. E. Albertson, 1	0	80		Oriskany gas, 80 M cu. ft.; abandoned
11	Putnam....	Pocatalico	0.87 mile N. of 38° 25′	0.87 mile W. of 81° 50′	4,358	Pen.-Conemaugh	L. Dev.-Oriskany	Hand and Smith	Nitro Industrial Corp., 6	0	80		Berea sand gas; dry in Oriskany; 2 ft. of sand
12	Roane.....	Geary	2.58 miles S. of 38° 35′	1.33 miles E. of 81° 10′	6,057	Pen.-Conemaugh	L. Dev.-Oriskany	Godfrey L. Cabot, Inc.	T. F. Smith, 879	0	0	0	Salt water in Oriskany; abandoned
13	Roane.....	Harper	5.23 miles N. of 38° 30′	1.0 mile E. of 81° 30′	5,448	Pen.-Conemaugh	L. Dev.-Oriskany	Ohio Valley Gas Corp.	M. C. Larch, 2	0	0	0	Dry in Oriskany; abandoned
14	Wirt.......	Burning Springs	1.80 miles N. of 39° 00′	1.55 miles E. of 81° 20′	4,886	Pen.-Conemaugh	L. Dev.-Oriskany	Carnegie Natural Gas Co. and Glen W. Roberts	W. C. Patterson, 1	15	82		Oil and gas in Elizabeth (?) at 2285; 50 M cu. ft. gas in Oriskany; filled by salt water
15	Wirt.......	Burning Springs	4.57 miles N. of 38° 55′	0.7 mile E. of 81° 15′	5,370	Perm.-Dunkard	M. Dev.-Shale	Godfrey L. Cabot, Inc.	W. Hoffman, 1-876	0	0	0	Dry hole
16	Wirt.......	Burning Springs	5.48 miles N. of 38° 55′	1.35 miles E. of 81° 20′	5,281	Pen.-Conemaugh	L. Dev.-Oriskany	Glen W. Roberts	L. R. and J. A. Roberts, 500	0	0	0	Shale gas, 50 M cu. ft. at 4065; Oriskany oil show; salt water; abandoned
17	Wirt.......	Tucker	1.75 miles N. of 39° 00′	1.78 miles E. of 81° 30′		Perm.-Dunkard		Roberts Bros. and Carnegie N. G. Co.	Walter Huffman, 1-1529	0	0	0	Dry hole
18	Wood......	Tygart	4.38 miles N. of 39° 10′	1.22 miles E. of 81° 35′	4,681	Perm.-Dunkard	L. Dev.-Oriskany	W. H. Bickel et al.	Reese Blizzard, 1	6	27		Oriskany oil and gas; not improved by shot

TABLE 3.—*Oriskany Sand Wildcats Drilling in West Virginia in January*, 1938

No.	County	Magisterial District	Location		Drilled by	Property and Well No.	Last Reported Depth, Ft.	Remarks
			Lat.	Long.				
1	Clay............	Otter	2.63 miles N. of 38° 35′	81° 00′ W.	Pgh. & W. Va. Gas Co.	Jessie Chapman, 7644	6,327	Showing Oriskany gas, 3-10-38
2	Hampshire.......	Mill Creek	0.4 mile S. of 39° 15′	1.9 mi. W. of 78° 50′	Maryland N. G. Utilities Corp.	Clower & Parker, 2	None	Drilling
3	Harrison........	Eagle	2.1 miles N. of 39° 25′	2.3 mi. W. of 80° 20′	Lumberport-Shinnston Gas Company	E. E. Heldreth	5,800	Deeper drilling of old well
4	Jackson.........	Ravenswood	5.37 miles N. of 38° 50′	1.10 mi. W. of 81° 40′	W. H. Pettry	D. O. Curry, 1	4,716	Showing 50 M cu. ft. in Oriskany; fishing
5	Jackson.........	Ripley	3.95 miles N. of 38° 45′	1.28 mi. W. of 81° 40′	Potter Dev. Co.	Wm. T. Chancey, 1	1,320	Drilling
6	Kanawha........	Elk	0.36 mile S. of 38° 15′	2.25 mi. W. of 81° 20′	Cameron O. & G. Co.	Henry Hansell, 1	1,500	Skidded rig and started new
7	Wirt............	Tucker	2.83 miles S. of 39° 05′	1.09 mi. W. of 81° 30′	Roberts Bros. and Carnegie N. G. Co.	W. O. Caplinger, 1-1524	5,434	Dry in Oriskany; drilling deeper
8	Wood...........	Harris	39° 05′ N.	2.9 mi. W. of 81° 40′	Potter Dev. Co.	W. H. Orem, 1	580	Drilling
9	Wood...........	Steele	5.50 miles S. of 39° 90′	4.34 mi. W. of 81° 30′	Belmont Quadrangle Drilling Co.	C. D. White, 1	3,800	Drilling

New wells, outside of the proved areas, are now drilling to the Oriskany in Clay, Harrison, Jackson, Kanawha, Wirt and Wood Counties, and a test to the Clinton sand (Sil.) is progressing in Hampshire County where the structure is highly folded.

Table 2 shows the result of wildcat drilling, mainly to the Oriskany sand, throughout the state in 1937. Table 3 shows the exploration now in progress. Table 4 gives the details of Oriskany drilling in Kanawha County.

A very good account of exploration in the Oriskany sand in West Virginia is afforded in a recent paper by Lafferty.[1] The Elk-Poca pool of Kanawha County, however, has been considerably extended to the northwest and southwest since the completion of Mr. Lafferty's paper.

TABLE 4.—*Oriskany Sand Wells, Kanawha County, West Virginia*

Magisterial District	Completed before 1937				Completed in 1937					Number of Wells Drilling in Jan. 1938
	Gas Wells		Dry in Oriskany	Total Number of Wells	Gas Wells		Dry in Oriskany	Total Number of Wells	Total Number of Wells	
	Number of Wells	M Cu. Ft. Gas			Number of Wells	M Cu. Ft. Gas				
Big Sandy	1	0	1	1	0	0	0	0	1	1
Cabin Creek	2	0	2	2	0	0	1	1	3	2
Charleston	1	0	1	1	0	0	0	0	1	0
Elk	25	106,051	5	31[1]	37	178,210	3	40	71	27
Jefferson	0	0	1	1	0	0	0	0	1	0
Loudon	7	2,703	4	11	0	0	1	1	12	1
Malden	19	47,971	3	22	13	20,547	1	14	36	8
Poca	9	74,187	0	9	45	487,292	0	45	54	67
Union	0	0	0	0	5	5,905	0	5	5	6
Washington	0	0	0	0	0	0	0	0	0	1
	64	230,912	17	78	100	691,954	6	106	184	113

[1] Includes one oil well completed in 1934 with 158 bbl. daily production.

OPERATING TECHNOLOGY

Routine handling of oil and gas wells has been mainly followed through the year. In Wayne County, however, a Koppers phenolate process for purifying sour gas from the Newburg sand was installed. In Kanawha County some operators are now using a Peerless automatic separator in the extraction of gasoline from the Oriskany gas. In this device the gas goes into a tank, where the gasoline is thrown out by a series of baffles and the outlet valve is automatically tripped when enough gas pressure has accumulated.

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[1] R. C. Lafferty: *Bull.* Amer. Assn. Petr. Geol. (Feb. 1938) **22,** No. 2, 175–188.

Pipe Lines and Markets

Several large pipe lines were built in 1937 to handle the new Oriskany sand gas of Kanawha County. As of Dec. 1, 1937, United Fuel Gas Co. completed and put into operation a new line from Cedarville, Gilmer County, northward to Majorsville, Marshall County. From Cedarville northward for 7 miles to Camp compressor station, the line is of 20 in. outside diameter. From Camp compressor, 3 miles east of Glenville, the line is thereafter 16 in. O.D. for the remaining 83 miles. This 90-mile line affords to United Fuel a means of transporting 50,000,000 to 60,000,000 cu. ft. of gas daily from its existing lines at Cedarville to the lines of Manufacturers Light and Heat Co., an affiliate, at Majorsville. Camp compressor contains two units and affords a working pressure of about 325 pounds.

As of about Dec. 1, 1937, also, Godfrey L. Cabot, Inc., completed a 12-in. O.D. line from its Oriskany sand gas wells in the Elk-Poca pool, near Sissonville, Kanawha County, northeastward 42 miles to its Oakes compressor station near Big Bend, Calhoun County. From Oakes compressor gas will move through existing Cabot lines to a connection with Manufacturers Light and Heat Co., a few miles distant. For the present no compression is required in the field, the gas being moved by the impulse of rock pressures in the wells. The operating pressure of the line is 300 to 350 lb. and should afford a daily capacity of 30,000,000 cu. ft. or more.

In 1937, also, Cabot built an 8-in. line from the Oriskany gas wells near Sissonville southward to the vicinity of Charleston. From this point gas may move through an existing 6-in. Cabot line to the Campbell-Davis Creek pool southeast of Charleston. From the latter pool another new 8-in. line of Cabot, built in 1937, continues southeastward to Jackson station of Hope Natural Gas Co. in the vicinity of Chelyan, Kanawha County. The new construction affords to Cabot a considerable further outlet for Oriskany gas.

In 1937, Cabot also built an 8-in. line from a point near Beckley, Raleigh County, eastward 21 miles to the city of Hinton, Summers County, where the company will distribute gas.

The price of crude oil in West Virginia, $1.82 per barrel as of Dec. 1, 1937, has been a discouraging factor against new operations. The field, or well-mouth, price of gas, also, has sharply declined. The best price that an operator may now obtain is about 12¢ per M cu. ft., and there are many indications of a further decline in 1938.

BY COUNTIES

Table 5 shows by counties the new development in West Virginia during 1937. This information is mainly gathered from trade journals and private reports. The summary of completions differs considerably from that published by the West Virginia Department of Mines, because of the lag occurring between completion dates and reports to the department. There is no comparison for initial well capacities because these are not reported to any public agency.

TABLE 5.—*Summary of New Development in West Virginia during* 1937

County	Number of Wells Drilled	Oil		Gas		Dry Holes
		Number of Wells	Bbl. per Day	Number of Wells	M Cu. Ft. per Day	
Boone	62	4	22	54	18,170	4
Braxton	38			31	12,041	7
Brooke	2	1				1
Cabell	49			48	17,863	1
Calhoun	78	16	184	46	38,366	16
Clay	15	10	94	3	496	2
Doddridge	8		1	8	2,550	
Fayette	2			2	368	
Gilmer	100	6	46	82	63,816	12
Hancock	6	4	10			2
Harrison	15			15	3,440	
Jackson	10	4	13			6
Kanawha	147	5	61	134	754,969	8
Lewis	10			9	2,335	1
Lincoln	53	8	104	44	25,680	1
Logan	2			2		
Marion	22	3	10	17	6,733	2
Marshall	19	2	22	16	8,221	1
Mason	3	1	1	1	100	1
Mingo	5			4	3,725	1
Monongalia	15	2	15	11	2,003	2
Nicholas	1			1	100	
Pleasants	40	17	24	10	1,542	13
Putnam	7			5	2,100	2
Ritchie	127	42	249	56	17,357	29
Roane	44	16	152	16	15,147	12
Taylor	1			1	1,350	
Tyler	28	13	43	5	5,670	10
Upshur	11			10	2,542	1
Wayne	28	1	5	26	17,010	1
Wetzel	39	11	79	19	23,779	9
Wirt	36	14	42	4	534	18
Wood	18	13	61		50	5
Total	1,041	193	1,238	680	1,048,057	168

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Oil Development and Production in Wyoming in 1937

By E. W. Krampert*

Oil development continued active in Wyoming during 1937, with much of the interest centered on prospecting for new pools, following a rather intensive seismograph play in 1936.

The new fields of Lance Creek, Medicine Bow and Quealy were the centers of intense development in proved areas, but routine drilling occurred in most old fields. A new and deeper producing horizon (the Leo sand) was opened up in the Lance Creek field, which materially extends the producing area and will probably account for continued active development during 1938.

The discovery in 1936 of oil in the Eocene Wasatch formation at Powder Wash, northwestern Colorado, tended for a time to stimulate prospecting in the deep Tertiary basins, but this interest as rapidly declined after drilling several failures on similar structures and the discovery that the productive area at Powder Wash itself was very small.

A most interesting test of an Eocene structure was drilled by The Superior Oil Company of California on the South Baggs structure, in Carbon County, Wyoming. South Baggs is one of the best developed structures in the Red Desert Washakie Basin, which also includes the Hiawatha gas field and the Powder Wash gas and oil field.

The Superior Oil Co. started the well according to contract but apparently had lost interest in the prospects, for it abandoned the well at 2138 ft. without testing the oil-bearing and gas-bearing horizons of the Wasatch.

The Sinclair Wyoming Oil Co. drilled a deep test in the Muskrat gas field to the Madison. This well discovered oil in the Embar formation, which was considered noncommercial because of depth. After the Embar was abandoned the hole was plugged back and the various sands tested by shooting through the casing with the Lane-Wells gun. The Lakota sand was found to contain high-pressure gas and the well was completed as a 24-million-foot gasser at 2175 lb. rock pressure. This is a new sand in an old field.

The Italo Petroleum Co. drilled a flank well on the Hamilton dome structure and found oil in the lower Embar formation. This merely extends the limits of production, as one old well on the structure had

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* Consulting Geologist, Casper, Wyoming.

TABLE 1.—*Oil and Gas Production in Wyoming*

Line Number	Field, *County*	Age, Years to End of 1937	Area Proved, Acres	
			Oil	Oil and Gas[a]
1	Alkali Butte, *Fremont*	9	40	
2	Allen Lake, *Carbon*	4	0	
3	Ant Hills, *Niobrara*	10	40	
	Baxter Basin (South), *Sweetwater*			
4	Frontier	15	0	
5	Dakota	15	0	
6	Total	15	0	
	Baxter Basin (North), *Sweetwater*			
7	Dakota	11	0	
8	Sundance	9	0	
9	Total	11	0	
10	Badger Basin, *Park*	7	300	0
	Big Muddy, *Converse*			
11	Shannon	21	2,000	0
12	Wall Creek	21	2,600	0
13	Dakota	15	400	0
14	Total	21	2,600	0
	Big Sand Draw, *Fremont*			
15	Wall Creek	20		
16	Lakota	7		
17	Total	20		
18	Billy Creek, *Johnson*	16		
19	Black Mountain, *Hot Springs*	14	300	
	Bolton Creek, *Natrona*			
20	Sundance	17	50	
21	Embar	17	50	
22	Total	17	50	
23	Boone Dome, *Natrona*	17	0	0
24	Bunker Hill, *Carbon*	1	0	0
	Byron Dome, *Big Horn*			
25	Frontier	15	0	0
26	Sundance	8	40	0
27	Embar-Tensleep	5	2,950	0
28	Total	15	2,950	
29	Circle, *Fremont*	14	250	0
30	Dallas-Derby, *Fremont*	54	350	0
	Dutton Creek, *Carbon*			
31	Shannon	11	0	0
32	Muddy	11	150	0
33	Total	11	150	0
34	East Allen Lake, *Carbon*	1	0	0
35	East Lance Creek, *Niobrara*	19	400	
	West Ferris, *Carbon*			
36	Dakota	16		
37	Sundance	12		
38	Total	16		
39	Eight Mile Lake, *Carbon*	14		
	Elk Basin, *Park*			
40	Frontier	22	580	0
41	Dakota	16	0	0
42	Total	22	580	0
43	Enos Creek, *Hot Springs*	14	0	0
44	Ferris, *Carbon*	20	200	0
45	Fourbear, *Park*	9	500	0
	Frannie, *Park*			
46	Tensleep	9	500	0
47	Madison	8	10	0
48	Total	9	510	0
	Garland, *Park*			
49	Frontier	30	40	0
50	Dakota	18	0	0

[a] Footnotes to column heads and explanation of symbols are given on page 313.

TABLE 1.—(*Continued*)

Line Number	Area Proved, Acres		Total Oil Production, Bbl.				Total Gas Production, Millions Cu. Ft.			
	Gas	Total	To End of 1937	During 1936	During 1937	Daily Average during Nov. 1937	To End of 1937	During 1936	During 1937	Maximum Daily during 1937
1	300	300	8,130	0	0	0	0	0	0	0
2	200	200					779	754	25	*y*
3	0	40	7,378	0	0	0				
4	7,467	7,467					7,054	1,532	1,965	
5	4,310	4,310					12,191	1,913	2,303	
6	7,467	7,467					19,245	3,446	4,269	36
7	1,280	1,280					7,603	1,945	1,585	
8	2,280	2,280					4,599	845	586	
9	2,280	2,280					12,202	2,790	2,172	13
10	0	300	156,223	14,820	68,853	252				
11	0	2,000	*x*	*x*	*x*	*x*				
12	0	2,600	*x*	*x*	*x*	*x*				
13	0	400	*x*	*x*	*x*	*x*				
14	0	2,600	25,255,249	519,032	484,217	1,278				
15	1,200	1,200					46,485	3,246	4,239	
16	300	300					0	0	0	0
17	1,200	1,200					46,485	3,246	4,239	
18	700	700					2,393	383	380	*y*
19		300	205,743	48,564	43,679	136				
20		50	*x*	0	*x*	0				
21		50	*x*	0	*x*	0				
22		50	48,500	0	3,500	10				
23	300	300					4,071	18	23	
24	480	480					0		0	0
25	500	500					3,153	376	277	*y*
26	0	40	14,000	0	0	0				
27	0	2,950	1,179,103	283,338	403,765	100				
28	500	2,950	1,193,103	283,338	403,765	100	3,153	376	277	*y*
29	0	250	0	0	0	0				
30	0	350	2,499,438	215,575	202,363	571				
31	800	800					1,090	163	102	*y*
32	0	150	218,138	20,211	18,027	56				
33	800	800	218.138	20,211	18,027	56	1,090	163	102	*y*
34	640	640					0	0	0	0
35	150	550	440,000	11,000	10,500	30	0	0	0	0
36	3,100	3,100					8,040	10	10	
37	3,500	3,500					16,139	329	180	
38	3,500	3,500					24,179	339	190	
39	250	250					4,870	98	120	
40	0	580	10,659,766	180,575	122,191	300				
41	1,200	1,200					22,769	1,682	1,832	*y*
42	1,200	1,200	10,659,766	180,575	122,191	300	22,769	1,682	1,832	
43	500	500					0	0	0	0
44	200	200	484,401	7,204	477		*y*	*y*	*y*	*y*
45	0	500	0	0	0	0				
46	0	500	2,318,189	411,072	459,967	1,513				
47	0	10	87,073	5,500	4,323	12				
48	0	510	2,405,262	416,572	464,290	1,525				
49	1,000	1,000	342,700	2,700	0	0	29[a]		29[a]	*y*
50	1,200	1,200	0		0	0	20,419[a]	147[a]	50[a]	*y*

TABLE 1.—(*Continued*)

Line Number	Number of Oil and/or Gas Wells: Completed to End of 1937	During 1937: Completed	During 1937: Abandoned	At End of 1937: Temporarily Shut Down	At End of 1937: Producing Oil Only	At End of 1937: Producing Oil and Gas[b]	At End of 1937: Producing Gas Only	At End of 1937: Total Producing	Depth, Average in Feet: Bottoms of Productive Wells	Depth, Average in Feet: To Top of Productive Zone	Oil Production Methods at End of 1937, Number of Wells: Flowing	Pumping	Gas-lift	Injection into Reservoir[c]	Pressure, Lb. per Sq. In.[d]: Initial	Average at End of 1936	Average at End of 1937	Character of Oil, Approx. Average during 1937, Gravity A.P.I. at 60° F.: Maximum	Minimum	Weighted Average
1	3	0	0	3	0	0	0	0	4,600	4,570	0	1	0		*y*	*y*	*y*	*x*	*x*	36
2	3	0	0	0	0	0	3	3	2,175	2,100					920	*y*	*y*			
3	2	0	0	0	0	0	0	0	3,957	3,951	0	0	0		*x*	*x*	*x*	*x*	*x*	36
4	13	1	0	0	0	0	12	12	2,400	2,200					800	740				
5	11	0	0	2	0	0	11	11	3,500	3,000					815	760				
6	24	1	0	2	0	0	22	22							785	700	685			
7	3	0	0	0	0	0	3	3	3,100	2,950					1,335	1,150	1,080			
8	2	0	0	0	0	0	2	2	3,400	3,350					1,485	1,190	1,080			
9	6	1	1	0	0	0	5	5												
10	3	1	0	0	3	0	0	3	8,500	8,250	3	0	0		*y*	*y*	*y*	*y*	*y*	48
11	35	0	0	25	10	0	0	10	1,250	1,200	0	10	0		*x*	*y*	*y*	*y*	*y*	31
12	134	0	0	0	134	0	0	134	3,400	3,260	0	134	0		*x*	*y*	*y*	*y*	*y*	32
13	5	0	0	0	5	0	0	5	4,700	4,600	0	5	0		*x*	*y*	*y*	*y*	*y*	36
14	174	0	0	25	149	0	0	149			0	149	0							
15	10	0	0	0	0	0	10	10	2,800	2,300					1,300	*y*	750			
16	1	0	0	1	0	0	0	0	4,350	4,300					1,860	1,860	1,860			
17	11	0	0	1	0	0	10	10												
18	9	1	1	0	0	0	8	8	3,250	3,200					1,150	*y*	710			
19	6	0	0	0	6	0	0	6	3,350	2,900		6			*x*	*x*	*x*	*y*	*y*	24
20	8	0	0	0	2	0	0	2	1,120	1,015		2			*x*	*x*	*x*	*y*	*y*	22
21	6	0	0	0	1	0	0	1	2,050	2,025		1			*x*	*x*	*x*	*y*	*y*	32
22	14	0	0	0	3	0	0	3				3								
23	4	0	0	2	0	0	2	2	2,200	2,150					750	*y*	200			
24	5	3	1	2	0	0	0	0	1,480	1,224					500		500			
25	2	0	0	0	0	0	2	2	2,500	2,400	0	0	0		1,000	*y*	370			
26	1	0	0	1	0	0	0	1	4,209	4,205	0	1	0		*x*	*x*	*x*	*y*	*y*	32
27	15	3	0	0	15	0	0	15	5,700	5,300	0	15	0		*x*	*x*	*x*	*y*	*y*	25
28	18	3	0	1	15	0	2	18			0	16	0							
29	2	0	0	2	0	0	0	0	655	170	0	2	0		*y*	*y*	*y*	*y*	*y*	23
30	72	0	0	10	42	0	0	42	1,200	700	0	42	0		*x*	*x*	*y*	*y*	*y*	23
31	5	0	0	0	0	0	5	5	1,700	1,600					440	*y*	310			
32	3	0	0	1	3	0	0	3	4,900	4,850	0	3	0					*y*	*y*	34
33	8	0	0	1	3	0	5	8			0	3	0							
34	2	2	0	2	0	0	0	0	2,088	2,000					1,050	1,050	1,050			
35	3	1	0	1	1	0	1	1	4,008	3,808	0	1	0		*y*		*y*	*y*	*y*	42
36	2	0	0	0	0	0	2	2	2,300	2,200					1,000		200			
37	11	0	0	0	0	0	11	11	2,700	2,600					1,140		200			
38	13	0	0	0	0	0	13	13												
39	4	0	0	3	0	0	1	1	3,500	3,400					1,724	*y*	600			
40	149	0	7	0	142	0	0	142	1,200	1,000		142	0	G				*y*	*y*	43
41	6	1	0	0	0	0	6	6	2,500	2,400					925	*y*	523			
42	155	1	0	0	142	0	6	148				142								
43	3	0	0	1	0	0	0	0	2,850	2,600					750		730			
44	25	0	0	25	0	0	0	0	1,650	1,600		8			1,020	*y*	125	*y*	*y*	36
45	1	0	0	1	0	0	0	0	3,350	3,270		1						*y*	*y*	15
46	12	0	0	0	11	0	0	11	2,800	2,770	0	11	0					*y*	*y*	28
47	2	0	0	0	1	0	0	1	3,013	3,012	1	0	0					*y*	*y*	18
48	14	0	0	0	12	0	0	12			1	11	0							
49	50	0	4	0	0	0	4	4	900	700	0	0	0		*x*	*y*	*y*	*y*	*y*	42
50	10	0	0	0	0	0	3	3	1,600	1,500	0	0	0		745	*y*	150			

TABLE 1.—(*Continued*)

Line Number	Character of Oil, Approx. Average during 1937		Character of Gas, Approx. Average during 1937		Producing Rock						Number of Dry and/or Near Dry Holes to End of 1937	Deepest Zone Tested to End of 1937	
	Sulphur Per Cent	Base[e]	B.t.u. per Cu. Ft.	Gal. Gasoline per M Cu. Ft.	Name	Age[f]	Character[g]	Porosity[h]	Net Thickness, Average in Feet	Structure[i]		Name	Depth of Hole, Ft.
1	*y*	M	*y*	*y*	Morrison	Jur	S	Por	30	A	18	Chugwater	5,460
2			*y*	*y*	Sundance	Jur	S	Por	40	A	4	Chugwater	4,083
3	0.1	M			Dakota	CreU	S	Por	6	A AF	2	Lakota	4,257
4			1,020	*y*	Frontier	CreU	S	Por	16	AF	5		
5			760	*y*	Dakota	CreU	S	Por	50	AF			
6										AF	5	Nuggett	3,822
											6	Chugwater	4,200
7			1,000	*y*	Dakota	CreU	S	Por	20	AF			
8			935	*y*	Sundance	Jur	S	Por	15	AF			
9											3	Jurassic	4,546
10	*y*	P			Frontier	CreU	S	Por	49	A	0	Frontier	8,725
11	*y*	M			Shannon	CreU	S	Por	65	A			
12	0.17	M			Wall Creek	CreU	S	Por	100	A			
13	0.18	M			Dakota	CreU	S	Por	15	A			
14											226	Madison	6,597
15			1,020	*y*	Wall Creek	CreU	S	Por	150	A			
16			1,020	*y*	Lakota	CreU	S	Por	40	A			
17											3	Sundance	5,345
18			890	*y*	Frontier	CreU	SH	Por	20	A	6	Big Hornlime	7,775
19	2.85	A			Embar-Tensleep	Per-Pen	L-S	Cav-Por	135	A	2	Madison	3,832
20	2.8	A			Sundance	Jur	S	Por	10	Af			
21	3.0	A			Embar	Per	L	Cav	15	AF			
22											11	Amsden	2,867
23			*y*	*y*	Shannon	CreU	S	Por	70	A	1	Niobrara	5,200
24			*y*	*y*	Shannon	CreU	S	Por	250	A	3	Sundance	6,791
25			*y*	*y*	Frontier	CreU	S	Por	30	A			
26	0.38	M			Sundance	Jur	S	Por	4	A			
27	2.2	A			Embar-Tensleep	Per-Pen	L-S	Cav-Por	130	A			
28											10	Amsden	6,700
29	2.84	A			Embar-Tensleep	Per-Pen	L-S	Cav-Por	50	A		Tensleep	650
30	2.4	A			Embar-Tensleep	Per-Pen	L-S	Cav-Por	150	A	23	Tensleep	1,400
31			*y*	*y*	Shannon	CreU	S	Por	40	A			
32	0.3	M			Muddy	CreU	S	Por	30	A			
33										A	1	Sundance	5,488
34			1,020	*y*	Sundance	Jur	S	Por	48	A	2	Sundance	2,180
35	0.14	M	*y*	*y*	Dakota	CreU	S	Por	95	A	5	Madison	6,434
36			1,060	*y*	Dakota	CreU	S	Por	30	A			
37			1,060	*y*	Sundance	Jur	S	Por	110	A			
38										A	1	Tensleep	4,690
39			1,060	*y*	Dakota	CreU	S	Por	50	A	4	Chugwater	4,560
40	0.14	P			Frontier	CreU	S	Por	40	AF			
41			*y*	*y*	Dakota	CreU	S	Por	55	AF			
42										AF	39	Dakota	2,450
43			*y*	*y*	Frontier	CreU	S	Por	40	A	0	Dakota	3,992
44	0.45	M	1,060	*y*	Mowry-Dakota	CreU	S	Por	25	A	35	Embar	4,600
45	3.88	A			Tensleep	Pen	S	Por	60	A	0	Tensleep	3,350
46	2.5	A			Tensleep	Pen	S	Por	100	AF			
47	3.3	A			Madison	Mis	L	Cav	1	AF			
48										AF	4	Madison	3,230
49	0.15	P	1,020	*y*	Frontier	CreU	S	Por	35	AF			
50			1,020	*y*	Dakota	CreU	S	Por	50	AF			

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Age, Years to End of 1937	Area Proved, Acres	
			Oil	Oil and Gas[a]
51	Embar-Tensleep	10	160	0
52	Madison	6	2,000	0
53	Total	30	2,000	0
54	Golden Eagle, *Hot Springs*	18	0	0
55	Gooseberry, *Park*	1	500	0
	Grass Creek, *Hot Springs*			
56	Frontier	23	1,400	0
57	Embar-Tensleep	16	2,000	0
58	Total	23	2,000	0
59	Greybull, *Big Horn*	29	640	0
60	Hamilton, *Hot Springs*	19	2,000	0
61	Hidden Dome, *Washakie*	20	200	0
62	La Barge, *Lincoln-Sublette*	14	950	0
63	Lake Creek, *Hot Springs*	12	100	0
	Lance Creek, *Niobrara*			
64	Dakota	22	1,000	0
65	Sundance	7	1,700	0
66	Minnelusa	1	5,000	0
67	Total	22	5,000	0
68	Lander (Hudson), *Fremont*	19	340	0
69	Little Buffalo Basin, *Park*	23	0	0
70	Little Polecat, *Park*	19	0	0
	Lost Soldier, *Sweetwater*			
71	Frontier	21	160	0
72	Dakota-Lakota	18	450	0
73	Sundance	11	160	0
74	Tensleep	7	160	0
75	Total	21	450	0
	Mahoney Dome, *Carbon*			
76	Dakota	18	0	0
77	Sundance	13	0	0
78	Tensleep	8	200	0
79	Total	18	200	0
80	Maverick Springs, *Fremont*	20	1,400	0
81	Medicine Bow, *Carbon*	3	0	800
82	Midway, *Natrona*	7	200	0
	Mule Creek (East), *Niobrara*			
83	Lakota	17	220	0
84	Minnelusa	7	100	0
85	Total	17	220	0
	Mule Creek (West), *Niobrara*			
86	Dakota	8	170	0
87	Minnelusa	6	400	0
88	Total	8	570	0
89	Muskrat, *Fremont*	10	200	0
90	North Garland (Danker Domes), *Park*	22	0	0
91	North Casper Creek, *Natrona*	6	100	0
92	North Sunshine, *Park*	10	150	0
93	Notches, *Natrona*	15	400	0
	Oregon Basin, *Park*			
94	Dakota	25	0	0
95	Embar-Tensleep	11	10,000	0
96	Total	25	10,000	0
97	Osage, *Weston*	17	10,000	0
	Pilot Butte, *Fremont*			
98	Niobrara	21	250	0
99	Muddy	8	0	0
100	Total	21	250	0
101	Pitchfork, *Park*	7	300	0
102	Plunkett, *Fremont*	16	45	0

TABLE 1.—(*Continued*)

Line Number	Area Proved, Acres		Total Oil Production, Bbl.				Total Gas Production, Millions Cu. Ft.			
	Gas	Total	To End of 1937	During 1936	During 1937	Daily Average during Nov. 1937	To End of 1937	During 1936	During 1937	Maximum Daily during 1937
51	1,650	1,650	0		0	0	20,628[1]	18,878[1]	[1]	*y*
52	500	2,000	2,602,899	543,045	856,454	2,500	871[1]	0[1]	871[1]	*y*
53	1,650	2,000	2,945,599	545,745	856,454	2,500	41,850	19,025	950	*y*
54	120	120					2,250	0	0	0
55	0	500	1,696	0	1,696					
56	0	1,400	24,263,910	552,085	408,325	900				
57	0	2,000	1,738,427	1,517	242,410	1,000				
58	0	2,000	26,002,337	553,602	650,735	1,900				
59	160	800	245,212	0	62	0	*x*	0	0	0
60	0	2,000	4,538,501	368,911	411,590	1,100				
61	640	640	243,199	83,613	129,586	210	27,000	0	0	0
62	0	950	5,111,140	428,436	381,704	1,000				
63	0	100	5,000	0	2,500	0				
64	3,500	3,500	4,385,553	35,000	36,553	100	59,800	900	0	
65	0	1,700	6,625,960	1,843,486	4,112,474	12,800	3,842	962	2,880	
66	0	5,000	116,107	0	116,107	500	0	0	0	
67	0	5,000	11,127,620	1,878,486	4,265,134	13,400	63,642	1,862	2,880	
68	0	340	1,868,895	109,116	112,779	315				
69	4,800	4,800					15,848	1,301	1,397	
70	500	500					837	144	136	
71	0	160	2,080,873	54,038	26,835	60				
72	0	450	11,496,207	122,794	106,913	300				
73	0	160	4,749,746	288,334	261,412	725				
74	0	160	570,889	0	64,889	360				
75	0	450	18,897,715	465,166	460,049	1,445				
76	1,400	1,400	800				14,410	100	10	
77	1,660	1,660	0				4,223	650	184	
78	0	200	1,500	0	0	0				
79	1,660	1,660	2,300	0	0	0	56,633	750	194	
80	0	1,400	0	0	0	0				
81	0	800	1,548,451	184,920	1,363,531	4,375	1,335	285	1,050	
82	0	200	175,617	14,668	10,149	32				
83	0	220	1,200,826	6,826	0	0				
84	0	100	3,750	0	0	0				
85	0	220	1,204,576	6,826	0	0				
86	0	170	*y*	*y*	*y*	*y*				
87	0	400	*y*	*y*	*y*	*y*				
88	0	570	36,000	5,421	7,316	30				
89	500	500		Not commercial			4,582	758	1,099	
90	800	800					30	9	10	
91	0	100	1,874	0	0	0				
92	0	150	0	0	0	0				
93	0	400	170,000	0	0	0				
94	1,300	1,300					1,785	229	261	
95	0	10,000	8,628,147	915,041	1,447,106	2,200				
96	1,300	10,000	8,628,147	915,041	1,447,106	2,200	1,785	229	261	
97	0	10,000	3,939,425	267,274	280,151	800				
98	0	250	541,829	9,189	10,640	20	0	0	0	0
99	400	400					0	0	0	0
100	400	400	541,829	9,189	10,640	20				
101	0	300	0	0	0	0				
102	0	45	11,700		Abandoned					

TABLE 1.—(*Continued*)

Line Number	Number of Oil and/or Gas Wells								Depth, Average in Feet		Oil Production Methods at End of 1937			Injection into Reservoir[c]	Pressure, Lb. per Sq. In.[d]			Character of Oil, Approx. Average during 1937		
		During 1937		At End of 1937							Number of Wells					Average at End of		Gravity A.P.I. at 60° F.		
	Completed to End of 1937	Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Oil and Gas[b]	Producing Gas Only	Total Producing	Bottoms of Productive Wells	To Top of Productive Zone	Flowing	Pumping	Gas-lift		Initial	1936	1937	Maximum	Minimum	Weighted Average
51	1	0	0	0	0	1	1	1	3,200	3,000	0	0	0		1,470	*y*	1,110	*y*	*y*	19
52	13	5	1	0	12	0	0	12	4,400	3,600	11	1	0		1,470	*y*	1,110	*y*	*y*	19
53	74	5	5	0	12	0	8	20			11	1	0							
54	3	0	0	0	0	0	0	0	3,000	2,250					1,175	Exhausted				
55	3	1	0	1	0	0	0	0	6,049	5,669	0	1	0					23.6	21.5	22
56	316	0	0	0	315	0	0	315	1,200	800	0	315	0	G				*y*	*y*	44
57	15	0	0	0	15	0	0	15	4,000	3,600	0	15	0					*y*	*y*	23
58	331	0	0	0	330	0	0	330			0	330	0							
59	14	0	0	14	0	0	0	0	1,050	1,000	0	14	0		*x*	Exhausted		*y*	*y*	48
60	33	1	0	1	31	0	0	31	3,250	2,700	0	32	0					*y*	*y*	26
61	28	8	3	0	16	0	1	16	1,600	1,200	0	16	0		725	Exhausted		*y*	*y*	47
62	113	3	0	0	93	0	0	93	1,000	650	0	93	0					45	19	31
63	3	0	0	1	0	0	0	0	3,760	3,730	0	1	0		*x*	*x*	*x*	*y*	*y*	26
64	78	0	1	11	3	0	12	26	3,665	2,820	0	14	0		910			*y*	*y*	42
65	51	14	0	2	46	0	0	46	4,100	3,500	42	4	0		1,600			49	41	44
66	13	13	1	0	12	0	0	12	5,600	4,900	12	0	0		2,000			*y*	*y*	44
67	142	27	2	2	72	0	12	84			54	28	0							
68	36	0	0	0	11	0	0	11	2,750	1,300	0	11	0					*y*	*y*	23
69	10	0	0	0	0	0	8	8	1,500	1,200					600	*y*	395			
70	1	0	0	0	0	0	1	1	4,100	3,900					1,375	1,200	1,114			
71	56	0	0	0	20	0	0	20	900	175	0		*y*	G				*y*	*y*	32
72	41	0	0	0	24	0	0	24	2,100	1,375	0	30	*y*	G				*y*	*y*	32
73	14	0	0	0	5	0	0	5	2,100	1,875	0	24	*y*	G				*y*	*y*	32
74	1	0	0	0	1	0	0	1	4,000	3,900	1	5	0					*y*	*y*	35
75	112	0	0	0	50	0	0	50			1	0 59								
76	4	0	0	0	0	0	4	4	2,300	2,170					1,060	*y*	150			
77	9	0	0	0	0	0	5	5	2,760	2,600					1,170	*y*	200			
78	1	0	0	1	0	0	0	0	4,760	4,600	1	0	0					*y*	*y*	34
79	14	0	0	1	0	0	9	9			1	0	0							
80	32	0	0	32	0	0	0	0	1,700	1,450	0	0	0					*y*	*y*	22
81	8	3	0	1	7	1	0	8	5,430	5,200	8	0	0		1,900	*y*	1,100	*y*	*y*	63
82	3	0	0	1	2	0	0	2	5,250	5,200	0	2	0					*y*	*y*	32
83	37	0	0	37	0	0	0	0	1,550	1,500	0	37	0					*y*	*y*	32
84	1	0	0	1	0	0	0	0	3,180	3,170	0	1	0					*y*	*y*	32
85	38	0	0	38	0	0	0	0			0	38	0							
86	43	0	0	0	19	0	0	19	350	170	0	19	0					*y*	*y*	37
87	1	0	0	0	1	0	0	1	2,830	2,800	0	1	0					*y*	*y*	35
88	44	0	0	0	20	0	0	20			0	20	0							
89	3	1	0	0	0	0	2	2	5,700	4,350					{2,200 1,600}	*y*	{2,200 1,260}	*y*	*y*	*y*
90	4	0	0	0	0	0	4	4	2,400	2,200					400	*y*	*y*			
91	2	0	0	2	0	0	0	0	3,210	3,200		0	0					*y*	*y*	23
92	2	0	0	1	0	0	0	0	3,700	3,475	0	1	0					*y*	*y*	16
93	5	0	0	1	0	0	0	0	2,850	2,800	0	1	0					*y*	*y*	23
94	4	0	0	0	0	0	4	4	1,550	1,500					720	*y*	340–670			
95	36	1	0	0	34	0	0	34	3,900	3,500	0	34						*y*	*y*	21
96	40	1	0	0	34	0	4	38			0	34								
97	435	15	7	10	352	0	0	352	1,525	1,500	0	352	0					*y*	*y*	41
98	13	1	1	0	13	0	0	13	1,000	800	0	13	0					*y*	*y*	36
99	2	0	0	2	0	0	0	0	3,370	3,350					800	*y*	800			
100	15	1	1	2	13	0	0	13				13								
101	1	0	0	1	0	0	0	0	3,950	3,750	0	0	0					*y*	*y*	18
102	15	0	0	0	0	0	0	0	500	250	0	0	0					*y*	*y*	42

TABLE 1.—(*Continued*)

Line Number	Character of Oil, Approx. Average during 1937		Character of Gas, Approx. Average during 1937		Producing Rock						Number of Dry and/or Near Dry Holes to End of 1937	Deepest Zone Tested to End of 1937	
	Sulphur Per Cent	Base[e]	B.t.u. per Cu. Ft.	Gal. Gasoline per M Cu. Ft.	Name	Age[f]	Character[g]	Porosity[h]	Net Thickness, Average in Feet	Structure[i]		Name	Depth of Hole, Ft.
51	3.0	A	900	*y*	Embar-Tensleep	Per-Pen	L-S	Por-Cav	100	A			
52	3.0	A	900	*y*	Madison	Mis	L	Cav	300	A			
53											83	Madison	4,750
54			*x*	*x*	Mesaverde	CreU	S	Por	50	A	5	Cody	4,019
55	2.0	A			Embar-Tensleep	Per-Pen	L-S	Cav-Por	50	A	2	Tensleep	6,076
56	0.14	P			Frontier	CreU	S	Por	200	A			
57	2.6	A			Embar-Tensleep	Per-Pen	L-S	Cav-Por	200	A			
58										A	85	Amsden	4,335
59	0.0	P	*x*	*x*	Greybull	CreU	S	Por	20	AF	115	Tensleep	2,950
60	2.39	A			Embar	Per	L	Cav	110	AF	2	Embar	3,246
61	0.1*y*	P	*y*	*y*	Frontier	CreU	S	Por	5	AM	20	Morrison	2,785
62	0.18	M			Wasatch	Eoc	S	Por	150	AF	53	Hilliard	4,210
63	3.2	A			Embar	Per	L	Cav	30	A	2	Tensleep	3,830
64	0.14	M	*y*	*y*	Dakota	CreU	S	Por	65	A			
65	0.14	M	*y*	*y*	Sundance	Jur	S	Por	65	A			
66	0.14	M			Minnelusa	Pen	S	Por	60	A			
67												Granite	6,434
68	2.9	A			Embar-Tensleep	Per-Pen	L-S	Cav-Por	185	A	8	Tensleep	2,190
69			1,000	*y*	Frontier	CreU	S	Por	100	A	4	Mowry	1,670
70			*y*	*y*	Frontier	CreU	S	Por	15	A	0	Frontier	4,420
71	0.15	M			Frontier	CreU	S	Por	200	Af			
72	0.15	M			Dakota-Lakota	CreU	S	Por	80	Af			
73	0.15	M			Sundance	CreU	S	Por	300	Af			
74	1.4	M			Tensleep	CreU	S	Por	40	Af			
75										Af	37	Tensleep	4,009
76			1,140	*y*	Dakota	CreU	S	Por	30	A			
77			1,140	*y*	Sundance	Jur	S	Por	110	A			
78	1.3	M			Tensleep	Pen	S	Por	160	A			
79										A	6	Tensleep	4,690
80	2.9	A			Embar	Per	L	Cav	50	A	3	Tensleep	2,094
81	*y*	A	*y*	*y*	Sundance	Jur	S	Por	140	A	6	Chugwater	5,910
82	0.3	A			Wall Creek	CreU	S	Por	30	A	4	Chugwater	6,689
83	0.17	M			Lakota	CreU	S	Por	25	A			
84	2.4	A			Minnelusa	Pen	S	Por	10	A			
85										A	11	Minnelusa	3,185
86	0.1	M			Dakota-Lakota	CreU	S	Por	30	A			
87	1.0	M			Minnelusa	Pen	H	Fis	10	A			
88										A	24	Madison	3,047
89	*y*	A	1,060	*y*	Frontier-Lakota	CreU	S	Por	150	AF	5	Madison	8,200
90			*y*	*y*	Frontier	CreU	S	Por	30	AF	1	Frontier	2,800
91	*y*	A			Tensleep	Pen	S	Por	10	A	2	Tensleep	3,308
92	3.9	A			Tensleep	Pen	S	Por	60	A	1	Tensleep	3,712
93	1.7	A			Tensleep	Pen	S	Por	40	A	4	Tensleep	2,830
94			*y*	*y*	Dakota	CreU	S	Por	35	Af			
95	3.3	A			Embar-Tensleep	Per-Pen	L-S	Cav-Por	150	Af			
96										Af	8	Madison	4,160
97	0.10	P			Newcastle	CreU	S	Por	10	ML	56	Minnelusa	2,235
98	0.1	P			Niobrara	CreU	H	Fis	*x*	A			
99			*y*	*y*	Muddy	CreU	S	Por	18	A			
100										A	46	Sundance	4,630
101	3.87	A			Tensleep	Pen	S	Por	40	A	0	Tensleep	3,903
102	0.19	P			Mowry	CreU	H	Fis	*x*	N	18	Embar	2,500

previously tested this horizon but had reported it as in the Tensleep formation.

The total production from a few of the larger fields is shown in Table 3, for comparative purposes.

Gas production showed a large decline in 1937 because the 1936 figure included a large loss of gas from a wild well in the Garland field. Actually the gas produced for consumption in 1937 showed a small increase over 1936.

PRODUCTION PRACTICES

Production practice in Wyoming has shown little change during 1937. The method of casing through sands and perforating the productive

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Age, Years to End of 1937	Area Proved, Acres	
			Oil	Oil and Gas[a]
103	Poison Spider, *Natrona*	19	400	
104	Iron Creek, *Natrona*	15	80	
105	Powder River, *Natrona*	7	0	
106	Quealy, *Albany*	4	160	
107	Rex Lake, *Albany*	14	200	
	Rock Creek, *Carbon*			
108	Dakota	20	1,300	
109	Sundance	3	500	
110	Total	20	1,300	
	Salt Creek, *Natrona*			
111	1st Wall Creek	29	4,350	
112	2nd Wall Creek	20	21,450	
113	Lakota	13	2,030	
114	Sundance	12	660	
115	Tensleep	7	640	0
116	Total	29	21,450	0
117	Shannon, *Natrona*	48	200	0
118	Sheep Creek, *Fremont*	3	200	0
119	Simpson Ridge, *Carbon*	13	160	0
120	South Casper Creek, *Natrona*	15	240	0
121	South Sunshine, *Park*	11	300	0
122	Spindletop, *Natrona*	9	80	0
123	Spring Creek, *Park*	8	2,000	0
124	Spring Valley, *Uintah*	37	400	0
	Teapot Dome, *Natrona*			
125	Wall Creek	15	640	2,000
126	Shale	15	x	0
127	Total	15	640	2,000
128	Torchlight, *Big Horn*	22	600	0
129	Warm Springs, *Hot Springs*	20	160	0
130	Waugh Dome, *Hot Springs*	4	100	0
	Wertz Dome, *Carbon*			
131	Frontier	12	0	0
132	Dakota	17	0	0
133	Lakota	10	0	0
134	Sundance	8	0	0
135	Tensleep	1	250	0
136	Total		250	0
	Total		77,555	2,000

zones with the Lane-Wells gun type of perforator is attracting some attention and has been used in some instances. The electric logging of wells is becoming standard practice for correlation purposes, but has not been successful in determining the oil and gas content of producing horizons.

Stanolind undertook to develop the Tensleep horizon in the Salt Creek field in 1937, but completed only one small well. Several other tests are under way.

In 1937, The General Petroleum Co. started a test on the Cole Creek structure in Natrona County, 13 miles northeast of Casper, which will be a 1938 completion. This is an excellent structure, though deep, and the test will probably result in the discovery of a new oil field of major proportions.

TABLE 1.—(*Continued*)

Line Number	Area Proved, Acres		Total Oil Production, Bbl.				Total Gas Production, Millions Cu. Ft.			
	Gas	Total	To End of 1937	During 1936	During 1937	Daily Average during Nov. 1937	To End of 1937	During 1936	During 1937	Maximum Daily during 1937
103	400	400	856,162	75,411	110,751	460	5,600	Exhausted		
104	80	80	10,990	y	9,990	10	y	Exhausted		
105	150	150					0	0	0	0
106	0	160	357,251	86,714	270,537	875				
107	0	200	220,514	1,060	5,254	0				
108	0	1,300	16,865,074	467,441	443,633	1,735				
109	0	500	449,541	169,000	280,541	1,090				
110	0	1,300	17,314,615	606,441	724,174	2,825				
111	0	4,350	47,130,566	293,900	331,666	900				
112	0	21,450	207,235,274	4,604,700	4,447,574	12,300				
113	0	2,030	16,532,535	661,500	686,035	1,900				
114	0	660	5,951,837	454,900	434,937	1,300				
115	0	640	65,000	0	0	0				
116	0	21,450	276,915,212	6,015,000	5,900,212	16,400				
117	0	200	55,400		Abandoned					
118	0	200	10,060	10,000	60	0				
119	0	160	163,050	0	0	0				
120	0	240	2,359,384	105,689	118,865	500	11,292	Exhausted		
121	0	300	0	0	0	0				
122	0	80	8,919	0	8,919	25				
123	0	2,000	33,200	0	33,200	230				
124	0	400	101,593	3,000	4,303	15				
125	x	2,640	3,000,000	0	0	0				
126			700,764	7,287	6,477	28				
127	x	2,640	3,700,764	7,287	6,477	28				
128	0	600	96,000	0	0	0				
129	0	160	280,910	18,518	5,242	30				
130	0	100	187,846	14,197	81,649	248				
131	100	100					700	Abandoned		
132	500	500					34,100	500	100	
133	500	500					25,017	2,094	523	
134	200	200					2,000	200	400	
135		250	104,003	1,000	103,003	437				
136	500	250	104,003	1,000	103,003	437	61,817	2,600	1,023	
	35,927	107,232	433,606,037	14,487,802	19,595,869	53,468	408,737	40,258	22,629	

The Stanolind started a test in 1937 on the Beaver Creek structure in Fremont County. At the end of the year the Frontier sands containing gas had been reached, but the well is being continued to test the Dakota horizons also. This test should also be a 1938 completion and will probably result in the discovery of a new gas field.

The intense seismograph play of 1936 was followed by drilling tests in 1937 and some analysis of results is becoming available.

The seismograph as an adjunct to geology is a success in Wyoming, and the continued use of the method of checking geology in obscure or covered areas is assured.

TABLE 1.—(*Continued*)

Line Number	Number of Oil and/or Gas Wells								Depth, Average in Feet		Oil Production Methods at End of 1937				Pressure, Lb per Sq. In.[d]			Character of Oil, Approx. Average during 1937		
		During 1937		At End of 1937							Number of Wells					Average at End of		Gravity A.P.I. at 60° F.		
	Completed to End of 1937	Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Produicng Oil and Gas[b]	Producing Gas Only	Total Producing	Bottoms of Productive Wells	To Top of Productive Zone	Flowing	Pumping	Gas-lift	Injection into Reservoir[c]	Initial	1936	1937	Maximum	Minimum	Weighted Average
103	19	1	0	0	14	0	0	14	1,425	1,400	0	14	0		525	Exhausted		y	y	22
104	5	0	0	0	1	0	0	1	820	650	0	1	0		200	Exhausted		y	y	32
105	7	0	0	0	0	0	0	0	1,350	1,315					530	y	525			
106	17	11	1	0	15	0	0	15	3,320	3,260	0	15	0					y	y	35
107	4	0	0	0	3	0	0	3	3,900	3,800	0	3	0					y	y	34
108	60	0	0	0	41	0	0	41	3,300	2,600	0	41	0	G				y	y	35
109	11	2	0	0	11	0	0	11	3,250	3,150	3	8	0	G				y	y	33
110	71	2	0	0	52	0	0	52			0	49	0							
111	306	0			200				1,100	1,000								y	y	36
112	1,580	0							1,575	1,535				G				y	y	36
113	57	0			45				2,350	2,300				G				y	y	36
114	41	0			35				2,875	2,750				G				y	y	35
115	5	1		5					3,980	3,970				G				y	y	35
116	1,990	0	y	200	1,500	0	0	1,500										y	y	28
117	18	0	0	0	0	0	0		900	800	0	0	0					x	x	24
118	4	0	0	2	0	0	0	0	2,100	2,035	0	2	0					y	y	25
119	12	2	2	3	0	0	0	0	675	625	0	3	0					y	y	21
120	17	0	0	0	17	0	0	17	2,700	2,600	0	17	0					y	y	15
121	1	0	0	1	0	0	0	0	2,514	2,475	0	0	0					y	y	18
122	6	3	1	0	5	0	0	5	1,125	1,100	0	5	0					y	y	22
123	3	0	0	0	1	0	0	1	4,255	3,660	0	1	0					y	y	16
124	30	0	0	0	2	0	0	2	900	400	0	2	0					y	y	38
125	47	0	0	47	0	0	0	0	2,950	2,900	0	0	0					y	y	35
126	15	0	0	13	2	0	0	2	1,600	1,200	0	2	0					y	y	35
127	62	0	0	60	2	0	0	2			0	2	0							
128	30	0	0	30	0	0	0	0	600	400	0	0	0					y	y	46
129	44	0	0	20	17	0	0	17	800	700	0	17	0					y	y	21
130	2	0	0	0	1	0	0	1	3,807	3,775	0	1	0					y	y	28
131	2	0	0	0	0	0	0	0	2,260	2,210	0	0	0		850	Exhausted				
132	4	0	0	0	0	0	3	3	3.550	3,500	0	0	0		1,940	y	280			
133	3	0	0	0	0	0	3	3	3,750	3,700	0	0	0		1,940	y	280			
134	1	0	0	0	0	0	1	1	4,120	4,100	0	0	0		1,520	y	430			
135	2	1	0	0	2	0	0	2	5,886	5,859	2	0	0					y	y	35
136	10	1	0	0	2	0	7	9			2	0	0							
	4,515	97	25	600	1,458	1	132	3,185			81	1,555								

The method used by some of the Mid-Continent companies in shooting blanket areas without the advantage of previous geological study by experienced geologists has thus far proved a complete failure.

PRODUCTION

During the year 1937, Wyoming produced 19,595,869 bbl. of oil, a gain of 5,108,067 bbl. over 1936. This large increase was mainly due to the new development in the Lance Creek, Medicine Bow and Quealy fields, which contributed their first production in 1936. Heavy black oil from the Permian, Pennsylvanian and Mississippian continued to be a drug on the market with many fields shut in, but facilities for handling and

TABLE 1.—(*Continued*)

	Character of Oil, Approx. Average during 1937		Character of Gas, Approx. Average during 1937		Producing Rock							Deepest Zone Tested to End of 1937	
Line Number	Sulphur Per Cent	Base[e]	B.t.u. per Cu. Ft.	Gal. Gasoline per M Cu. Ft.	Name	Age[f]	Character[g]	Porosity[h]	Net Thickness, Average in Feet	Structure[i]	Number of Dry and/or Near Dry Holes to End of 1937	Name	Depth of Hole, Ft.
103	2.8	A	*y*	*y*	Sundance	Jur	S	Por	35	A	5	Granite	4,119
104	0.1	M	*x*	*x*	Dakota	CreU	S	Por	25	A	4	Sundance	1,633
105			*y*	*y*	Frontier	CreU	S	Por	35	A	14	Chugwater	3,460
106	0.2	M			Muddy-Dakota	CreU	S	Por	60	A	2	Sundance	4,207
107	0.37	M			Dakota	CreU	S	Por	50	A	1	Lakota	3,930
108	0.26	M			Dakota	CreU	S	Por	110	A			
109	0.26	M			Sundance	Jur	S	Por	100	A			
110											11	Embar	5,627
111	0.15	M			1st Wall Creek	CreU	S	Por	110	Af			
112	0.15	M			2nd Wall Creek	CreU	S	Por	65	Af			
113	0.15	M			Lakota	CreL	S	Por	20	Af			
114	0.4	M			Sundance	Jur	S	Por	70	Af			
115	1.3	M			Tensleep	Pen	S	Por	190	Af			
116	2.3	A								Af		Granite	5,400
117	*x*	M			Shannon	CreU	S	Por	75	MUP	41	Shannon	*y*
118	2.9	A			Embar	Per	L	Cav	75	A	2	Tensleep	3,905
119	0.17	M			Quealey	CreU	S	Por	40	A	15	Steele shale	6,931
120	4.5	A			Tensleep	Pen	S	Por	150	A	5	Tensleep	2,500
121	3.15	A			Embar	Per	L	Cav	40	A	0	Embar	2,514
122	3.24	A			Sundance	Jur	S	Por	25	A	8	Tensleep	2,705
123	3.91	A			Embar-Tensleep-Amsden	Per-Pen	L-S	Cav-Por	270	A	2	Amsden	4,255
124	*y*	M			Aspen	CreU	H	Fis	*x*	MC	65	Bear River	2,065
125	0.15	M			Wall Creek	CreU	S	Por	40	Af			
126	0.15	M			Shale	CreU	H	Fis	*x*	Af			
127										Af	10	Frontier	3,140
128	*y*	P			Mowry	CreU	SH	Por	50	A	95	Madison	4,165
129	3.24	A			Embar	Per	L	Cav	50	A	7	Tensleep	1,590
130	1.8	A			Embar	Per	L	Cav	35	A	5	Tensleep	4,246
131			1,060	0.25	Frontier	CreU	S	Por	50	A			
132			1,060	0.25	Dakota	CreU	S	Por	50	A			
133			1,060	0.25	Lakota	CreL	S	Por	40	A			
134			1,060	0.25	Sundance	Jur	S	Por	20	A			
135	1.4	A			Tensleep	Pen	S	Por	27	A			
136										A	2	Tensleep	5,883

market for the products are gradually increasing. Wyoming in 1937 produced 4,716,208 bbl. of heavy oil, an increase of 1,559,534 bbl. over 1936.

Salt Creek is still the largest producing light-oil field in the state, Lance Creek trailing closely for second place. It is probable that these fields will reverse positions for annual production in 1938. Oregon Basin

TABLE 2.—*Summary of Drilling Operations in Wyoming in 1937*

Important Wildcats Drilled in 1937

	County	Location			Total Depth, Ft.	Surface Formation	Deepest Horizon Tested
		Sec. Survey	Twp. Lat.	Rge. Long.			
1	Niobrara (Lance Creek)	35	36 N	65 W	5538	Pierre shale	Minnelusa
2	Niobrara (East Lance Creek)	29	36 N	64 W	6434	Pierre shale	Madison
3	Goshen (Jay Em)	28	29 N	62 W	3090	White River	Granite
4	Laramie (Cheyenne Area)	13	13 N	68 W	9385	White River	Chugwater
5	Natrona (Cole Creek)	21	35 N	77 W	4626	Laramie	Shannon
6	Carbon (East Allen Lake)	18	22 N	78 W	2180	Niobrara	Chugwater
7	Carbon (Simpson Ridge)	20	21 N	80 W	5619	Mesaverde	Steele shale
8	Carbon (Bunker Hill)	29	27 N	89 W	1488	Mesaverde	Shannon
9	Carbon (South Baggs)	7	12 N	92 W	2138	Wasatch	Wasatch
10	Fremont (Muskrat)	1	33 N	92 W	8112	Steele shale	Madison
11	Fremont (Beaver Creek)	3	33 N	96 W	6575	Wasatch	Frontier
12	Johnson (Billy Creek)	17	48 N	82 W	7775	Steele shale	Big Horn
13	Hot Springs (Hamilton Dome)	11	44 N	98 W	3200	Benton shale	Embar
14	Big Horn (Paintrock)	12	49 N	91 W	2300	Sundance	Madison
15	Park (Gooseberry)	33	47 N	100 W	5996	Cody shale	Tensleep
16	Park (Garland)	24	56 N	98 W	4749	Cody shale	Madison
17	Carbon (Cherokee Ridge)	5	12 N	95 W	5680	Green River	Wasatch
18	Sweetwater (Black Fork)	2	18 N	110 W	5330	Wasatch	Wasatch

	Drilled by	Initial Production per Day		Pressure, Lb. per Sq. In.	Remarks
		Oil, U. S. Bbl.	Gas, Millions Cu. Ft.	Casing	
1	Ohio Oil Co.	1800	2.5		Leo sand discovery
2	Conoco Oil Co.		8.5		Gas in Dakota. Failure in lower sands
3	Ohio Oil Co.				Failure. Seismograph high
4	Amerada Pet. Co.				Failure. Seismograph high
5	General Pet. Co.				Discovery in Shannon. Incomplete
6	Medicine Bow Oil Co.		25	1000	New gas field in 1936
7	Ohio Oil Co.				Failure. Test for subsurface structure
8	Ohio Oil Co.		5	300	New gas field
9	The Superior Oil Co.				Insufficient test on good structure
10	Sinclair-Wyoming		24	2175	New gas sand. Lakota in old field
11	Stanolind		Show		Incomplete test
12	Carter Oil Co.				Failure in deep sands old gas field
13	Italo Pet. Co.	50			Extends field
14	Wood-Callahan				Large flow water
15	General Pet. Co.	280			New black-oil field
16	Kinney Coastal	360	5	1600	Extends Madison pool
17	Ohio Oil Co.		3	200	Shallow gas only
18	Ohio Oil Co.				Failure on Tertiary basin structure

was the largest producer of black oil and will probably continue to hold this position for several years to come.

TABLE 3.—*Production of a Few Large Fields in* 1937
BARRELS OF 42 GALLONS

Field	Light Oil	Heavy Oil	Total
Salt Creek	5,900,212		5,900,212
Lance Creek	4,265,134		4,265,134
Oregon Basin		1,447,106	1,447,106
Garland		856,454	856,454
Rock Creek	724,174		724,174
Grass Creek	408,325	242,401	650,737
Big Muddy	484,217		484,217
Frannie		464,290	464,290
Lost Soldier	395,160	64,889	460,049
Byron		403,765	403,765
Elk Basin	122,191		122,191

Petroleum Development in Argentina during 1937

By Mario L. Villa*

Another increase in production and the discovery of new pools are the outstanding developments of the year 1937.

Production in 1937 totaled 16,354,706 bbl., compared to 15,457,953 bbl. in the previous year, an increase of 5.8 per cent, of which 5 per cent was due to the Yacimientos Petrolíferos Fiscales (Argentine Government Oil Fields) and 0.8 per cent to private companies.

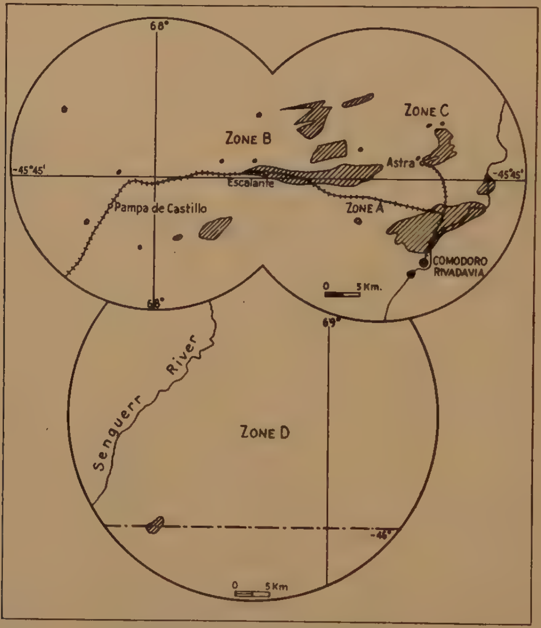

Fig. 1.—Oil-bearing zones, Territory of Chubut.

Table I shows that the most important gain in output was obtained in zone B of Comodoro Rivadavia, partly offset by a 5.7 per cent decrease in the Neuquén district. The fields of Salta and Mendoza show an increase of 4.4 and 39.1 per cent, respectively.

The determination of bottom-hole pressures was started by Yacimientos Petrolíferos Fiscales (Y.P.F.) in Comodoro Rivadavia and

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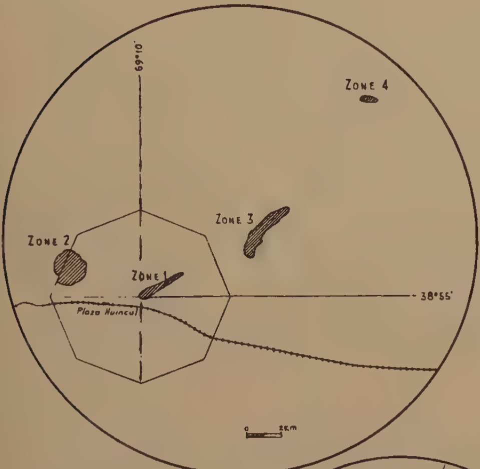
* Gerente General, Yacimientos Petroliferos Fiscales, Buenos Aires, Argentina.

Salta. The preliminary results show, for the end of 1937, the following averages:

Salta, southern part of the Tartagal zone, 550 lb. per sq. in.
Comodoro Rivadavia, eastern part of zone B, 540 lb. per sq. in.

2



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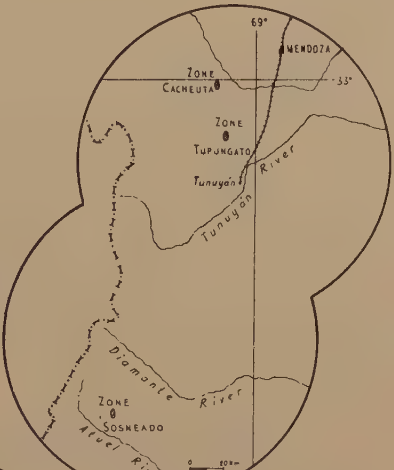

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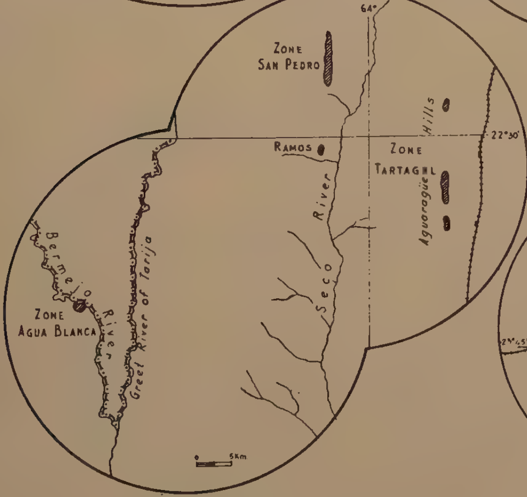

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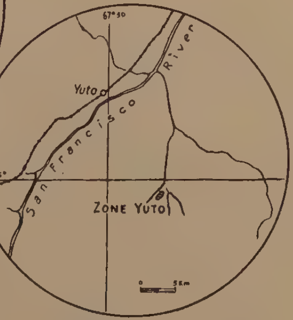

Fig. 2.—Oil-bearing zones, Territory of Neuquén.
Fig. 3.—Oil-bearing zones, Province of Mendoza.
Fig. 4.—Oil-bearing zones, Province of Salta.
Fig. 5.—Oil-bearing zones, Province of Jujuy.

Y.P.F. will extend these measurements to the rest of its fields and expects to be able to give all the necessary data next year.

Production is still suspended in zone D of Comodoro Rivadavia. In zone B of that field, the discovery by Y.P.F. of new pools added considerable acreage to the proven area. Wells E5, E6, E10, T63 and S109 are worthy of note. Completing the data of Table 2, it may be mentioned that the well T63 reached a depth of 5733 ft., finding a new oil-bearing horizon at 5717 to 5730 ft. that gave an initial production of 314 bbl. per day, and that the well S109 found a producing sand at a depth of 4431 to 4460 ft. with an initial production of 189 bbl. per day. Both wells have helped to extend the productive area.

Another important discovery was made by the well 1296 of Y.P.F., which established that the deep producing horizon found in 1936 in the old central field (zone A), is also present in the southern part of the field at a distance of 4½ km. from the previous test. Well 1632 drilled by Y.P.F. in a location to the west of the old central field encountered, at a depth of 3047 to 3060 ft. below sea level, a new oil-producing horizon deeper than any other known in the zone.

The wildcat S.C.1, in the Territory of Santa Cruz, about 550 km. south of the Comodoro Rivadavia field, was completed as a dry hole at a depth of 3621 ft. This has been another enterprise of the Government

TABLE 1.—*Oil and Gas Production in Argentina in* 1937

Line Number	Field, *Territory or Province*	Age, Years to End of 1937	Area Proved, Acres		Total Oil Production, Bbl.				Total Gas Production, Millions Cu. Ft.	
			Oil and Gas[a]	Total	To End of 1937	During 1936	During 1937	Daily Average during Nov. 1937	To End of 1937	During 1936
	Comodore Rivadavia, *Terr. Chubut*									
1	Zone A	30	14,079	14,079	94,502,048	5,956,051	5,985,268	15,939	149,425	9,142
2	Zone B	13	17,537	17,537	33,909,994	5,529,350	6,477,932	19,298	23,651	4,447
3	Zone C	21	3,458	3,458	15,263,194	1,074,005	942,795	2,459	8,895	988
4	Zone D	4			24,549	610	188			
	Plaza Huincul, *Terr. Neuquén*									
5	Zone 1	19	138	138	1,544,780	80,474	76,794	144	1,482	141
6	Zone 2	11	1,252	1,252	2,680,697	342,339	378,815	968	5,365	635
7	Zone 3	13	504	504	8,807,214	599,235	519,661	1,333	8,542	635
8	Zone 4	3	57	57	35,859	23,235	9,995		776	776
	Dept. Orán, *Prov. Salta*									
9	Zone Tartagal	11	729	729	3,453,814	322,551	367,084	817	5,118	706
10	Zone San Pedro	9	254	254	7,498,699	1,321,686	1,368,006	3,591	8,154	1,341
11	Aqua Blanca	11	119	119	784,457	127,309	113,761	289		
12	Yuto, *Prov. Jujuy*	1	32	32	3,315		1,572	4		
13	Cacheuta, *Prov. Mendoza*	6	1,060	1,060	156,608	40,205	71,586	245		
14	Tupungato, *Prov. Mendoza*	4	242	242	52,873	20,077	14,970	31		
15	El Sosneado, *Prov. Mendoza*	12	100*y*	100*y*	237,082	20,826	26,279	56		
16	Total		39,561	39,561	168,955,183	15,457,953	16,354,706		211,408	18,811

[a] Footnotes to column heads and explanation of symbols are given on page 313.

company in its efforts to add new fields to the already proven ones in the country.

Two wildcats, NH.1 and NE.8, were completed as dry holes by Y.P.F. in the Plaza Huincul district (Territory of Neuquén). The latter found shows of oil. Well No. 282, north of zone 1, encountered gas at various depths and shows of oil of slight importance.

Y.P.F. drilled, in the Province of Salta, the well R.P.4 (Rio Pescado), which encountered important oil-producing sands. This well, included in Tables 1 and 2 in the Agua Blanca zone, was completed at a depth of 4195 ft. and rendered an initial production of 352 bbl. per day after drilling through the most important flows of gas yet registered in the Province of Salta.

Well Ramos No. 8, south of San Pedro, drilled by the Standard Oil Co., was completed at a depth of 3493 ft., having encountered gas and oil sands at 3169 to 3194 ft. with an initial production of 151 bbl. per day.

The wildcat CD.5 was completed by Y.P.F. as a dry hole at a depth of 6386 feet.

TABLE 1.—(*Continued*)

	Total Gas Production, Millions Cu. Ft.		Number of Oil and/or Gas Wells							Depth, Average in Feet		Oil Production Methods at End of 1937						Pressure, Lb. per Sq. In.[d]	
				During 1937		At End of 1937						Number of Wells							Average at End of
Line Number	During 1937	Maximum Daily during 1937	Completed to End of 1937	Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Gas Only	Total Producing	Bottoms of Productive Wells	To Top of Productive Zone	Flowing	Pumping	Gas-lift	Air-lift	Miscellaneous	Injection into Reservoir[c]	Initial	1936
1	9,390	27	2,285	50	25	275	1,718	18	1,736	2,086	1,902	33	1,671	5		9	G 31 W 2	1,030	30
2	4,130	12	524	145	12	57	357	10	367	3,280	2,952	14	298	23		22	G 9	730	35
3	600	17	659	57	4	129	364	16	380	2,132	1,968		356			8		300	15
4			13	2	2	3		3	3	2,624	2,296								55
5	212	0.7	86	2	2	9	49	2	51	1,787	1,705		49				G 5	150	65
6	529	1.4	140	14	4	14	115	5	120	2,410	2,197	13	102				G 5	210	105
7	600	0.7	212	1	1	34	136	9	145	2,706	2,542		136				G 11	180	70
8			5	2	2	2				3,313	3,280							40	
9	670	2.1	155	7		34	95		95	3,280	1,984	11	79	4	1		G 1	60	60
10	1,200	3.5	44	7		4	26		26	2,850	2,794	22	2	2			G 5	600	500
11			7	1		3	6		6	2,460	2,400	5				1			
12			5	5	3		2		2	5,248	5,240	2							
13			44	14	4	4	21		21	2,394	1,787		20			1			
14			17	5	4	3	9		9	2,624	2,345	9							
15			[y]	[y]	[y]	[y]	[y]		[y]	551	544	[y]	[y]	[y]	[y]	[y]			
16	17,331		4,196	312	63	571	2,898	63	2,961			109	2,713	34	1	41			

The well Lomas de Olmedo No. 2 was drilled by the Standard Oil Co. and completed as a dry hole at a depth of 4904 feet.

An unsuccessful wildcat was drilled by the Ultramar Co. in Cuchuma to a depth of 2981 ft., encountering only shows of oil, and the Galena Signal Oil Co. completed another one in La Cruz, at 5277 ft., as a dry hole.

In the Province of Mendoza, Y.P.F. completed wells C15 and T17 mentioned in Table 2, which had an initial production of 19 and 6 bbl. per day, respectively. Well C34, however, also drilled by Y.P.F. on the same structure tested by the C16, registered an initial production of 314 bbl. of oil per day.

TABLE 1.—(*Continued*)

	Character of Oil, Approx. Average during 1937					Character of Gas, Approx. Average during 1937		Producing Rock							Deepest Zone Tested to End of 1937	
	Gravity A.P.I. at 60° F.															
Line Number	Maximum	Minimum	Weighted Average	Sulphur, Per Cent	Base[e]	B.t.u. per Cu. Ft.	Gal. Gasoline per M Cu. Ft.	Name	Age[f]	Character[g]	Porosity[h]	Net Thickness, Average in Feet	Structure[i]	Number of Dry and/or Near-dry Holes to End of 1937	Name	Depth of Hole, Ft.
1	24.0	20.6	22.0	0.18	M	854	0.51	Chub. and Glaucon.	Cre	Ss	Por	29y	AF	144	Chubutiano	5,363
2	34.6	20.5	28.0	0.18	M	854	0.45	Chub. and Glaucon.	Cre	Ss	Por	33y	AF	100	Chubutiano	5,871
3	21.3	19.0	20.0	0.18	M	850	0.12	Chub. and Glaucon.	Cre	Ss	Por	13y	AF	94	Chubutiano	2,365
4	23.2	23.2	23.2	0.18	M	850	0.20	Chub. and Glaucon.	Cre	Ss	Por	26y	AF	5	Chubutiano	6,616
5	34.4	33.4	34.0	0.20	M	905	1.54	Dogger	Jur	S	Por	39y	Af, MU	23	Liásico	4,631
6	34.2	33.0	33.8	0.20	M	905	1.12	Dogger	Jur	S	Por	33y	Af, MU	11	Liásico	5,543
7	34.2	33.0	33.8	0.20	M	905	1.11	Dogger	Jur	S	Por	33y	Af, MU	24	Liásico	4,349
8	34.0	33.0	33.6	0.20	M	905	y	Dogger	Jur	S	Por	25y	Af, MU	4	Liásico	4,480
9	45.0	43.9	44.0	0.10	P	917	0.84	Gond. Aren. Sup.	Per-CreU	S	Por	33y	A	36	Gondwana	4,202
10	46.0	44.7	45.0	0.10	P	917	0.84	Gondwana	Per	S	Por	29y	A	6	Gondwana	3,200
11	23.2	22.8	23.0	0.10	P	917	0.30	Gond. Aren. U.	Per	S	Por	20y	A	3	Aren. U.	4,195
12	33.6	30.8	31.9	0.20	P			Hor. Calcáreo Dolomit.	CreU	S	Por	15y	AF	3	Areniscas Inf.	6,314
13	31.2	27.0	28.0	0.14	P			Rético	TriU	Ss	Por	13y	AF	10	Rético	4,241
14	33.0	31.0	32.0	0.11	P			Calchaquí	Ter	Ss	Por	16y	Af	4	Cretaceo	5,468
15	13.0	11.0	13.0	1.20	A			Ranchhouse	Ter inf. CreU	Ss	Por	13y	MIF	5		551
16														472		

TABLE 2.—*Summary of Drilling Operations in Argentina*

Important Wildcats Drilled in 1937

	Province or Territory	Location	Well Name	Total Depth, Ft.	Surface Formation	Deepest Horizon Tested	Drilled by	Initial Production per Day		Remarks
								Oil, U. S. Bbl.	Gas, Millions Cu. Ft.	
1	Chubut....	C. Rivadavia	E.5	4,871	Terciario Superior	Estr. con Dinosaurios	Y.P.F.	943		
2	Chubut....	C. Rivadavia	E.6	4,592	Terciario Superior	Estr. con Dinosaurios	Y.P.F.	566		
3	Chubut....	C. Rivadavia	E.10	4,352	Terciario Superior	Estr. con Dinosaurios	Y.P.F.	943		
4	Chubut....	C. Rivadavia	T.63	5,733	Terciario Superior	Estr. con Dinosaurios	Y.P.F.	314		
5	Chubut	C. Rivadavia	S.109	4,494	Terciario Superior	Estr. con Dinosaurios	Y.P.F.	189		
6	Santa Cruz	Coyle	SC.1	3,621	Terciario Superior	Triásico	Y.P.F.			Dry hole
7	Neuquén...	Plaza Huincul	NH.1	2,598	Estr. con Dinosaurios	Lias	Y.P.F.			Dry hole
8	Neuquén...	Plaza Huincul	282	4,631	Estr. con Dinosaurios	Lias	Y.P.F.			Shows of oil and gas
9	Neuquén...	Plaza Huincul	NE.8	3,870	Estr. con Dinosaurios	Lias	Y.P.F.			Shows of oil
10	Salta......	Campo Durán	CD.5	6,386	Terciario Subandino	Terciario Subandino	Y.P.F.			Dry hole
11	Salta......	L. de Olmedo	No. 2	4,904	Margas Color. Sup. (V)	Margas Color. Inf. (Wi)	Standard Oil Co.			Dry hole
12	Salta......	Río Pescado	RP.4	4,195	Terciario Subandino	Terciario Subandino (Areniscas Superiores)	Y.P.F.	352	250.135	
13	Salta......	Ramos	No. 8	3,493	Areniscas Superiores	Devónico?	Standard Oil Co.	151		
14	Salta......	Cuchuma	309	2,981	Areniscas Superiores	Areniscas Inferiores	Ultramar S.A.			Shows of oil
15	Salta......	La Cruz	289	5,277	Margas Color. Super.	Areniscas Inferiores	Galena Signal Oil Co.			Dry hole
16	Jujuy......	Yuto	JB.1	5,094	Areniscas Superiores	Paleozoico Inferior	Y.P.F.			Shows of oil
17	Mendoza...	Cacheuta	15	4,241	Estr. Calchaqueños	Rético	Y.P.F.	19		
18	Mendoza...	Tupungato	17	1,230	Estr. Jujeños	Estr. Jujeños	Y.P.F.	6		
19	Mendoza...	Río Salado	RS.1	4,966	Neocomiano	Dogger	Y.P.F.			Shows of oil

	In Proven Fields	Wildcats
Number of wells drilling Dec. 31, 1937	126	20
Number of oil wells completed during 1937	291	7
Number of gas wells completed during 1937	2	1
Number of dry holes completed during 1937	80	16

TABLE 3.—*Zones into Which the Oil-bearing Areas in Argentina Have Been Divided*[a]

Territory or Province	Zones	Location	Companies
Chubut......	A	Costa Atlántica (Comodoro Rivadavia)	Y.P.F., Ferrocarrilera, Industrial y Comercial y Cía. de Petróleo de C. Rivadavia
	B	Km. 27 Estación Escalante (Comodoro Rivadavia)	Y.P.F., Diadema Argentina y El Sindicato (Astra)
	C	Km. 20 Estación Astra (Comodoro Rivadavia)	Astra y Solano
	D	Pampa de María Santísima (Colonia Sarmiento)	Y.P.F.
Neuquén....	No. 1	Centro Octógono de Reserva (Plaza Huincul)	Y.P.F.
	No. 2	Oeste Octógono de Reserva (Plaza Huincul)	Y.P.F. y La República
	No. 3	Laguna Colorada (Plaza Huincul)	Y.P.F., Standard Oil y Astra
	No. 4	Bajo de Los Baguales (Plaza Huincul)	Y.P.F.
Salta........	Tartagal	Sierra Aguaragüé (Departamento Orán)	Y.P.F. y Standard Oil Co.
	San Pedro	Sierra del Río Seco (Departamento Orán)	Standard Oil Co.
	Agua Blanca	Juntas de San Antonio (Departamento Orán)	Standard Oil Co.
Mendoza....	Cacheuta	Cerro Cacheuta (Luján de Cuyo)	Y.P.F.
	Tupungato	Estación Tupungato	Y.P.F.
	Río Atuel	El Sosneado (San Rafael)	Compañía Río Atuel

[a] Location and production of zones is shown in charts (Figs. 1–5).

Oil Prospecting in Australia during 1936–1937

By W. G. Woolnough*

It is perhaps a little difficult for Americans fully to appreciate the slow progress in the search for oil in Australia. Conditions are so different from those in the United States that methods must also differ considerably.

Australia possesses an area almost exactly equal to that of the United States, but has a population of less than 7,000,000, and this population is concentrated almost entirely around the eastern and southern coasts of the continent. There are, therefore, vast "empty spaces" entirely unpopulated or exceedingly sparsely populated. The emptiness is due not to any lack of energy or initiative on the part of Australians but to the arid and waterless character of much of the country's interior. Throughout the greater part of the area that is comparable with the Mississippi drainage area of the United States, there is not a single flowing stream, and over most of it the rainfall is less than 7 in. a year. This hinders exploration and geological survey, and also isolates from potential markets many of the regions that otherwise might be considered worth prospecting.

Also, Australia consists of six independent and sovereign states. With the establishment in 1901 of the Commonwealth of Australia, the states retained complete control of lands and mineral rights. Each state has its own petroleum legislation, and the absence of a central controlling authority has tended to confusion and to the introduction of many complications in oil prospecting. There are three major "territories," administered by the Federal Government; namely, the Northern Territory, enclosed between the northern parts of Queensland and Western Australia, within Australia itself, and the Territories of Papua and New Guinea in the island of New Guinea. Land and mineral legislation in these territories is not uniform.

Furthermore, during the late twenties there occurred an orgy of company flotation and indiscriminate drilling, which resulted in the discovery of some definite indications of oil in three of the states and two of the territories, but which failed to develop any producing oil field in the common acceptation of the term. Much money was squandered,

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and the reaction, combined with the financial depression, caused an almost complete cessation of oil activities for several years.

During the past two years there has been a marked revival, partly attributable to returning prosperity but partly also to a certain degree of "oil education" of the population. Though there is still some uncritical acceptance of the statements of self-styled American experts, there is a healthier tendency to demand tangible evidences and to employ reputable advisers in the search. Most of the states and the two New Guinea territories have passed new oil legislation, which, though still far from satisfactory in many respects, is generally an improvement on the old laws, which were founded largely on the experience gained in dealing with gold and coal, both of which have been produced in large amounts in Australia for several generations.

Legislation

Queensland has adopted legislation recognizing the necessity for preliminary geological investigation before company promoting and prospecting drilling are entered upon. Prospecting permits are issued, which allow the holders to enter upon crown and private lands for survey purposes, but which do not confer upon the holders any exclusive rights. On discovery of apparent indications, an individual or company may apply for a lease of a limited area, and must commence drilling within three months of the granting of the lease. This title is of an exclusive character, giving its holder absolute rights of operation within the tenement. Leases are limited in area to 2500 acres, and there are conditions limiting to two the number of leases that can be taken up by one authority within the state.

In Victoria, mineral rights, including oil rights, were formerly held absolutely by the owners of the surface of crown lands alienated prior to 1893. This greatly complicated prospecting operations, as landowners could refuse entry and could impose any conditions they chose. The new Act has declared that, even under so-called "prior land" (land alienated prior to 1893) oil shall revert to the Crown in 1940. While this permits holders of such land to exercise their rights if they care to do so, it imposes a limit to their powers for obstruction. The Act, unfortunately, imposes unsatisfactory limits in respect to areas to be granted for leases, and is not regarded as altogether satisfactory.

In Western Australia a new Act has been passed which recognizes the necessity of orderly investigation prior to exploitation, and which has introduced many desirable reforms. However, the provisions made for areas of leases and for "reward leases" granted to discoverers of oil still do not satisfy many people, and there is a tendency on the part of operators to mark time in this state.

In New South Wales, South Australia and Tasmania, legislation has not been modified recently to any marked extent.

In both Papua and New Guinea ordinances have been promulgated with the view of controlling and regulating oil prospecting and of encouraging adequate preliminary geological survey in these geological *terrae incognitae* before expenditure of capital in drilling. Under these ordinances the areas that can be taken up as leases and licences are limited though liberal. To encourage exploitation by companies possessed of financial and technical resources greater than those of minor concerns, a provision has been inserted in the ordinances giving power to the proper authorities to grant exclusive concessions over areas up to 30,000 sq. miles for prospecting purposes, on condition that specified sums of money of considerable amounts shall be spent on approved operations within limited periods. All the active operations at present in both territories are confined to such large concessions.

PETROLEUM OIL SEARCH ACTS, 1936

In May 1936, the Commonwealth Government passed an Act appropriating the sum of £250,000 to assist in the search for petroleum in Australia and the Territories under its control, to be used in the form of pound for pound advances to persons engaged in the search along approved lines and in approved areas. The fund is administered by the Minister for the Interior of the Commonwealth Government, who is advised by a technical Oil Advisory Committee of three geologists. With the Minister for the Interior there are associated two other Commonwealth Ministers, forming a Cabinet subcommittee. According to the original Act, advances could be given only for drilling operations, but the Oil Advisory Committee recommended that, because geological survey was in a very backward condition, the Act should be amended so as to provide for financial assistance to those engaged in preliminary geological survey, scout drilling and other approved operations of a preparatory nature. The Act was amended to cover this provision in December 1936, such assistance to take the form of advances by the Commonwealth on the basis of £1 for £2.

The provision of these funds has proved a real incentive to activity in the search for oil, and none the less valuable is the degree of control given to the Commonwealth Government, through the Oil Advisory Committee, over the nature and location of prospecting operations; a control that, as already mentioned, it does not possess by virtue of constitutional rights over mineral resources, which are the property of the individual sovereign states.

STATE OF VICTORIA

Small amounts of heavy oil, suitable as lubricating stock, but devoid of gasoline and kerosene fractions, were discovered in the Gippsland district of eastern Victoria in 1937. Within about 5½ sq. miles, 28 wells have been sunk near the town of Lakes Entrance. In all of these more or less oil of similar quality has been encountered in glauconite sands of Oligocene age, resting unconformably on bedrock consisting of granite or metamorphosed sediments. The oil is associated with potable artesian water, from which it is extremely difficult to effect a sharp separation in drilling. One such artesian well supplies the town of Lakes Entrance with water, and small quantities of oil find their way into the domestic water supplies from this source.

After attempts extending over some years to exploit some of the wells on a commercial scale, with no financial success, most of the wells have been abandoned, and more or less effectively sealed.

Two wells, however, have been tested systematically by Austral Oil Drilling Syndicate No Liability, a Melbourne company, successors to South Australian Wells No Liability. One of these bores, known as Foster's bore, has yielded consistently over a period of 11 months small amounts of oil. The average over this period amounted to some 30 Imperial gallons per day. The oil is emulsified, necessitating treatment for dehydration.

During the latter part of 1937 tests were made on Midwest No. 2 bore, 700 yd. north of Foster's bore. Over a period of 12 weeks this bore produced 1290 gal. of oil, averaging 15 gal. a day.

All the bores near Lakes Entrance bottomed on bedrock at depths varying from 660 to 1472 ft. Claims that Midwest No. 2 passed through Tertiary formations to a depth of 3206 ft. are opposed to official records, which show that the formation drilled was biotite granite similar to that known to outcrop some 7½ miles to the northwards, which was encountered in several of the adjacent bores.

With financial assistance from the Commonwealth Government, it is proposed definitely to test the possibilities of this area by drilling three or four wells around Foster's and Midwest No. 2 bores, taking special precautions in entering the glauconite sands to eliminate water troubles as far as possible.

Throughout the deeper Tertiary basin west of Lakes Entrance, eight deep bores have been sunk. Traces of oil and/or gas have been claimed in some of these, and proved for a few, but the nature of the deposits at present is "not proven."

Still farther to the west, in the neighborhood of Sale and Longford, a definite plunging anticlinal structure has been delineated, partly by geological survey but chiefly by drilling. In the western (higher) portion of this structure the marine Oligocene beds in which the oil traces of Lakes Entrance have been encountered are replaced by a fresh-water, lignitic phase, which passes into the extensive and remarkable deposits of brown coal developed at Morwell, Yallourn, etc. The fresh-water phase has given no evidence of petroleum content. Hopes are entertained that at some point intermediate between Longford and Lakes Entrance oil-forming conditions may have been developed in the marginal facies between fresh-water and marine phases.

Ordinary methods of geological survey are not available in this area, since the Tertiary formations are unconformably overlain by thick Quaternary deposits of sand and gravel. The only available method of dealing with the problem (geophysical methods having proved inconclusive) is by scout drilling. Marker beds characterized by definite foraminiferal assemblages have been defined, and the Governments of the State of Victoria and of the Commonwealth are jointly carrying out a systematic scout drilling campaign, which promises, in the near future, to supply sufficient evidence to enable test wells to be located for the proving of the deposits.

Extensive areas of Tertiary marine deposits are known to exist in western Victoria and in the neighboring parts of the state of South Australia. Numerous wells have been sunk in these areas, and claims of discoveries of oil have been made, but such claims are without official verification. At present there is no activity in this part of Australia.

State of South Australia

There is no activity in the southeastern corner of South Australia. In other parts of the state, known to be occupied by older pre-Cambrian formations either at the surface or at shallow depths, desultory drilling "for oil" is carried on from time to time, mostly based on the supposed "indications" of the divining rod, and, of course, in direct opposition to all advice from official geologists. The Director of Mines of the State of South Australia has shown that large sums of money have been wasted in this hopeless drilling, in which 9923 ft. of plutonic igneous rocks of pre-Cambrian crystalline schists have been penetrated, out of a total of 41,666 ft. drilled up to March 1935.

State of Western Australia

Here also drilling operations are in abeyance temporarily. In the period between 1923 and 1930, eight bores were sunk within the basin of the Fitzroy River in the northern part of this state, which has an area of approximately 1,000,000 sq. miles. In several of these, small but definite evidences of oil were encountered in rocks of Permo-Carboniferous or Permian age. Since 1934 extensive and detailed geological surveys carried out by Dr. Arthur Wade for the Freney Kimberley Oil Co. have shown that not one of the earlier bores was suitably located in regard to structure. Also, these detailed surveys have removed many of the fallacies previously held in regard to this region, especially the incorrect belief that there was an absence of cover rocks suitable for the preservation and retention of oil supplies. It is now known that there are numerous horizons on which are developed great thicknesses of dense shale amply sufficient for the purpose. Further, the lithological character of some of the beds, and the abundance in them of organic remains, removes, to a large extent at all events, the fear that source materials might be absent. During the survey there have been completely delineated closed domal structures of major dimensions, such as would undoubtedly be vigorously tested for oil in any oil-producing country. If financial difficulties can be solved it may be expected that test drilling will be commenced.

Extensive and intensive geological survey has been carried out in the coastal regions of Western Australia between Carnarvon and Onslow, and somewhat promising structures involving Mesozoic and Tertiary beds have been brought to light. These areas are still under discussion, and it is not known whether or when a start will be made with test drilling.

STATE OF QUEENSLAND

There is greater activity in this very large state at the present time than in any other. Interest has centered here for many years; in fact, ever since a strong flow of petroliferous gas was struck at the town of Roma, 320 miles west of Brisbane, in drilling for artesian water in 1900. Much entirely speculative drilling followed this discovery, most of it without the slightest foundation on geological investigation. Although most of this drilling was abortive, a few wells did produce small amounts of genuine crude oil, and considerable amounts of petroliferous gas. The many failures led to discouragement, and to an almost complete cessation of drilling activity during the years of the financial depression; though activity was never entirely at a standstill even during that period.

Detailed geological survey by Oil Search Ltd. led to the drilling of a well at Warooby Creek, 6 miles east of Roma, in 1934, in which a further supply of petroliferous gas was proved. This supply, however, does not reach commercial dimensions under the geographical conditions prevailing, and at present the well is sealed down.

The same company extended its geological reconnaissance far and wide to the north of Roma, with results yielding a very real contribution to the knowledge of the stratigraphy of the widely extended Mesozoic formations of Central Queensland. The stratigraphic sequence has been worked out in considerable detail, and several complete domal structures have been mapped. On two of these, leases to prospect for petroleum have been secured from the Queensland Government, and drilling is actively in progress, with somewhat promising results.

At Hutton Creek, 60 miles north of Roma, a well has been sunk to a depth of 3715 ft., some indications of natural gas having been encountered. A larger drilling plant, made available to the company by the Commonwealth Government, has been installed, and operations, which have been temporarily suspended, should recommence before the end of 1937.

At Arcadia Dome, 85 miles north of Roma, a well has been sunk by means of an inadequate percussion plant, to a depth of 4110 ft. Large volumes of natural gas under noteworthy pressures have been encountered. The composition of these gases is interesting. Two analyses follow:

	At 3055 Ft. Per Cent	At 3170 Ft. Per Cent
Carbon dioxide	80.2	72.0
Air	Nil	8.0
Methane	12.9	11.0
Inert gas	4.7	7.1
Ethane and higher homologues	2.2	1.9
Density	1.33	1.28

As the effective limit of the drilling plant has been exceeded already, operations have been discontinued pending the making available by the Commonwealth Government of an up-to-date rotary outfit.

In 1929 the Roma Blocks Oil Co. drilled a well 8 miles northeast of Roma, reaching bedrock (granite) at a depth of 3561 ft. Just above bedrock a small supply of oil was encountered. Various eventualities, but chiefly the onset of the depression, caused the abandonment of operations at this point. With the renewal of interest the possibilities of this well have been reconsidered. Carefully controlled bailing tests, under the supervision of the Commonwealth Government, proved conclusively that the oil indications were genuine, if microscopic in amount, showing that, qualitatively at all events, the formations were petroliferous. The quality of the oil indicated that, if obtainable in sufficient quantity, commercially exploitable petroleum could be secured.

More detailed geological investigations, financially assisted by the Commonwealth Government, were therefore undertaken. Under the impression that surface outcrops were too poor to permit of geological mapping, attention was confined to scout drilling, with not very satisfactory results. Later, it was found that sufficiently intensive investigation was capable of bringing to light outcrops of sufficient continuity to be amenable to plane-table survey. This work has now shown the existence of a major domal structure not less than 3 miles long by 2 miles wide, with ample vertical closure. The original well, which produced small amounts of oil, is now known to be situated on the extreme edge of a minor wrinkle on the flanks of the main dome. In these circumstances, hopes are entertained that the drilling of a properly located test well may result in the discovery of oil in commercial quantities.

STATE OF NEW SOUTH WALES

Oil Search Ltd. is active in New South Wales. As a result of much extensive and intensive geological survey in the Hunter River Basin north of Sydney, and thence southwards to and beyond Sydney, the company has discovered and delineated two closed domal structures, and has been engaged in drilling them.

On Kulnura Dome, approximately 50 miles north of Sydney, a well has reached a depth of 5450 ft. After passing through 2706 ft. of epicontinental sediments of Triassic age, the bore penetrated 2560 ft. of fresh-water coal measures with marine intercalations. This great thickness of fresh-water beds was not expected, in view of the known developments of this phase exposed at the surface, and extensively worked for coal at no great distances north, south and west. Latest advices suggest that the coal measures have now been penetrated, and that the underlying marine beds of Permo-Carboniferous age have been entered. The bore is proceeding, and has entered upon an interesting phase. Small showings of inflammable gas have been encountered at intervals, but are not regarded as significant.

At Mulgoa Dome, only about 30 miles west of Sydney, a closed structure in Triassic rocks has been drilled to a depth of 3125 ft., the effective capacity of the plant employed. (Incidentally, it may be mentioned that the use of inadequate plant and methods has been one of the greatest drawbacks in the search for oil in Australia. Exceptionally high efficiency in drilling for artesian water constitutes a really serious difficulty in developing the quite different technique involved in drilling for oil.) Drilling has been suspended, and the company is considering whether or not to drill a new well with more efficient plant on the same structure. Large gas flows were encountered.

STATE OF TASMANIA

There is no activity in drilling for oil anywhere in this island state, nor are suitable structures known to exist there.

TERRITORIES OF PAPUA AND NEW GUINEA

Several of the major oil companies have taken up concessions under the new legislation, involving the expenditure of large sums of money in preliminary operations of a specified nature. While it is known that, in some instances, promising structures are under investigation, the reports of operations are confidential, and no details can be published at this stage.

Prior to 1930 the Anglo-Persian Oil Co., acting as an agent for the Commonwealth Government, carried out considerable geological mapping in both territories, but chiefly in Papua, and also did a considerable amount of drilling at Popo. While, unquestionably, there exist ample evidences of the existence of petroleum in highly folded rocks of Tertiary age, mechanical difficulties associated with the occurrence, on an unprecedented scale, of thick beds of bentonitic character, locally known as "running mudstones," rendered all drilling operations abortive with the technique then available. Improvements in the drilling of such heaving muds during the past few years has fostered the hope that drilling may now be undertaken with better hope of success.

An Australian company, the Papuan Apinaipi Co., has secured a concession over an area that includes the Popo district, where the previous unsuccessful drilling was done. It proposes to investigate another of the structures mapped by the Anglo-Persian company—the Apinaipi dome—by means of geological survey and scout drilling, with a view to location of a site for a test well. These operations are only in their initial stages at present.

Petroleum Developments in Austria, Hungary and Czechoslovakia

By Brandon H. Grove*

(New York Meeting, February, 1938)

Austria

The Zistersdorf field, near Vienna, continues to be Austria's only producing area. During the year the field was slightly extended by Rohöl Gewinnungs A.G. in its Rag 2, which in April came in for an initial 120 tons daily through an 8-mm. (0.315-in.) bean, from the twelfth Sarmat sand at 1447 m. (4747 ft.). The amount of fluid produced by this well has remained essentially constant, but after the first several months water appeared and increased to some 50 per cent of the total. Two subsequent extension wells, Rag 3 and Rag 5, northeast and west of Rag 2, found only water-bearing sands, and drilled through the main fault and into the Flysch at 1683 and 1401 m. (5522 and 4596 ft.), respectively. At the close of the year preparations were under way to deviate both wells away from the fault to test still deeper sands.

Within the previously proven area of the field Erdölproduction's Gösting VII came in flowing a maximum of 440 tons daily, the highest individual production yet recorded. This company's Gösting VIII also yielded an initial production of 20 tons daily, and its Gösting XI, drilling

Table 1.—*Oil and Gas Production in Austria, Hungary and Czechoslovakia*

Line Number	Country, *Field*	Age, Years to End of 1937	Area Proved, Acres				Total Oil Production, Bbl.[1]			
			Oil	Oil and Gas[a]	Gas	Total	To End of 1937	During 1936	During 1937	Daily Average during Nov. 1937
1	Czechoslovakia, *Gbely* (*Egbell*)	24	*y*	200	*y*	200	2,021,138	79,191	93,618	299
2	Czechoslovakia *Hodonin* (*Göding*)	18	*y*	150	*y*	150	843,768	64,343	31,890	117
3	Austria, *Zistersdorf*	8	*y*	90	0	90	371,433	44,163	237,482	686
4	Hungary, *Bükkszek*	1	20	0	0	20	8,2*xx*	0	8,2*xx*	35
5	Hungary, *Budafa-Puszta*	1	*y*	*y*	*y*	*y*	12,*xxx*	0	12,*xxx*	*y*

[a] Footnotes to table heads and explanation of symbols are given on page 313.
[1] One metric ton = 7 barrels.

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* Socony-Vacuum Oil Co., Inc., Hamburg, Germany.

in December in the Sarmat below 1100 m., showed an extremely favorable Schlumberger log.

As an important wildcat may be mentioned R.K. van Sickle 1, which attempted to extend the Zistersdorf producing area some 5 km. (3.1 miles) to the northeast. The well found all sands water-bearing, and was abandoned in the middle Sarmat at 1383 meters.

HUNGARY

During 1937 Hungary became for the first time an oil-producing country, through two widely separated discoveries of apparently very unequal importance.

At the beginning of the year a production test on the Eurogasco (Standard Oil Company of New Jersey) wildcat at Budafa-Puszta (Lispe) in southwestern Transdanubia near the Yugoslavian border, resulted in an initial flow of 380,000 cu. m. daily of gas accompanied by a small amount of crude oil, through a 20-mm. choke, and under a casinghead pressure of 84 atmospheres, from the lower Pannonian (Pliocene) between 1066 and 1136 meters.

Production was restricted to fuel for a second well, located ¾ km. to the east. In November, Budafa-Puszta 2 came in for an initial 70 tons daily of very high-grade oil, under 56 atmospheres casinghead pressure, from horizons between 1168 and 1179 m. in the lower Pannonian. It is said that excellent indications were also obtained in the Sarmat below 1522 m., but could not be tested because the hole is junked at this depth. No. 2 was shut in pending the construction of a pipe line to the railroad station at Csömödar-Paka, which was completed in December. At the close of the year the well was producing steadily 50 to 60 tons of oil through a 5-mm. bean, and drilling had begun on Budafa-Puszta 3,

TABLE 1.—(*Continued*)

	Total Gas Production, Millions Cu. Ft.				Number of Oil and/or Gas Wells							Depth, Average in Feet		Oil Production Methods at End of 1937					Pressure, Lb. per Sq. In.		
						During 1937		At End of 1937						Number of Wells						Average at End of	
Line Number	To End of 1937	During 1936	During 1937	Maximum Daily during 1937	Completed to End of 1937	Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Gas Only	Total Producing	Bottoms of Productive Wells	To Top of Productive Zone	Flowing	Pumping	Air-lift	Swabbing	Bailing	Initial	1936	1937
1	$20y$	7	4	0.02	$37y$	$2y$	y	$10y$	$5y$	y	y	790	540	y	0	0	0	y	y	x	x
2	y	46	y	y	$12y$	y	y	y	y	y	$1y$	485	425	y	y	0	0	y	y	x	x
3	x	y	y	y	16	9	2	2	11	0	11	3,444	3,280	1	8	1	1	0	y	y	y
4	0	0	0	0	14	14	6	0	8	0	8	340	335	0	6	0	0	2	30		30
5	y	0	y	14	2	2	0	0	0	0	2	3,805	3,674	2	0	0	0	0	1,050		y

situated 1½ km. to the east. The Budafa-Puszta wells are on a large east-west trending anticline found by the torsion balance, and the discovery appears to be of considerable importance.

Hungary's second oil field was discovered in April by a Government wildcat at Bükkszek, on the edge of the great Hungarian plain 125 km. east-northeast of Budapest. The oil comes from spotty sands in the middle Oligocene, at depths averaging about 100 m. The structural relationships are still uncertain.

Since its discovery 14 wells have been drilled at Bükkszek, 8 of which have given some production. The initial yield is small, averaging about one ton daily per well, and thus far the enterprise is of doubtful commercial worth.

Eurogasco's Mihalyi 1, which last year discovered a large potential production of carbon dioxide, has been prepared for the possible manufacture of dry ice, and a second well, Mihalyi 2, is being drilled near by. At the close of the year the latter was bottomed at 2374 m. in the lower Pannonian and had not yet encountered indications of importance.

CZECHOSLOVAKIA

There were no significant petroleum developments in Czechoslovakia during 1937. Production declined in the Apollo company's field at Hodonin (Göding), in Moravia, despite efforts to maintain it by drilling. The present producing area appears sharply limited by faults except to the south, and test wells have thus far failed to extend it in this direction. The proved area possesses theoretic possibilities for deeper production, which cannot be tested until adequate drilling equipment has been acquired.

TABLE 1.—(*Continued*)

Line Number	Character of Oil, Approx. Average during 1937					Character of Gas, Approx. Average during 1937		Producing Rock						Number of Dry and/or Near-dry Holes to End of 1937	Deepest Zone Tested to End of 1937	
	Gravity A.P.I. at 60° F.															
	Maximum	Minimum	Weighted Average	Sulphur, Per Cent	Base[e]	B.t.u. per Cu. Ft.	Gal. Gasoline per M Cu. Ft.	Name	Age[f]	Character[g]	Porosity[h]	Net Thickness, Average in Feet	Structure[i]		Name	Depth of Hole, Ft.
1	40	20	21	0.25	A, P	y	y	Sarmat Torton	Mio	SH	y	100	AF	7y	Flysch (Eocene?)	5,122
2	40	18	19	y	A	y	y	Sarmat	Mio	SH	y	65	AF	3y	Mediterran (Mio)	2,411
3	32	19	22	0.25	A, P	y	y	Sarmat	Mio	SS	20	450	AF	9	Sarmat	5,577
4	40	31	34	0.50	P	y	y	Rupelian	Olig	SH	y	12	AF	6	Carboniferous	2,296
5	y	y	40	y	P	y	y	Pannon	Pli	SS	y	50	A	0	Sarmat	5,799

Production in the government's field at Gbely (Egbell), in Slovakia, rose markedly during the year because of the success of wells in the new extension. The old field has been completely drilled up since 1928, and produces a maximum of 300 to 400 tons annually from the intermittent bailing of a few wells.

The apparent success of the Apollo company's wildcat at Ratiskovice, previously reported, proved short-lived. Production declined rapidly in a few days, and ceased completely within a month. A second well, drilled in the vicinity, also produced about 5 tons daily for a few days and then gave out entirely. It is probable that this oil came from secondary crevice accumulations, and well No. 2 is being deepened to a contemplated 800 m. into the Flysch basement, in the hope of discovering better reservoir conditions. At the close of the year it had reached 600 m. (about 400 m. in the Flysch) without encouraging results.

The Government continued its wildcatting effort at Jasina, in eastern Ruthenia, deepening the previous hole by some 100 m., to 1200 m. The well is still bottomed in Cretaceous Flysch, and is still encountering traces of oil and gas. A Government wildcat is also prospecting the Flysch at Staskov, in north central Slovakia.

TABLE 2.—*Important Wildcats Drilled in* 1937

	Country	Location			Total Depth, Ft.	Surface Formation
		District	Lat.	Long.		
1	Austria	Lower Austria	48°37′	16°40′	4,531	Pliocene
2	Hungary		47°50′	19°55′	2,296	Oligocene
3	Hungary	Transdanubia	46°30′	16°45′	5,801	Pliocene
4	Hungary	Transdanubia	46°30′	16°45′	4,921	Pliocene

	Deepest Horizon Tested	Drilled by	Initial Production per Day		Choke or Bean, Mm.	Pressure, Lb. per Sq. In.		Remarks
			Oil, U. S. Bbl.	Gas, Millions Cu. Ft.		Casing	Tubing	
1	Upper Miocene	Erdolproduction Ges.						Dry in middle Sarmat
2	Pennsylvanian	Hungarian state						Drilling in Carb. Basement
3	Upper Miocene	Eurogasco	1	14	20	1,200	850	
4	Upper Miocene	Eurogasco	800	*y*	5	850	525	

	Austria		Hungary		Czechoslovakia	
	In Proven Fields	Wildcats	In Proven Fields	Wildcats	In Proven Fields	Wildcats
Number of wells drilling Dec. 31, 1937	2	2	2	1	*y*	2
Number of oil wells completed during 1937	2	0	7	2	±30	0
Number of gas wells completed during 1937	0	0	0	1	*y*	0
Number of dry holes completed during 1937	1	1	5	0	*y*	1

The Rutgers company has acquired the minor Flysch production at Mikova, in the Ruthenian Carpathians, and is preparing for extensive test drilling in the vicinity.

No attempt was made during 1937 to begin the mining of the "dead" oil occurrence at Sokolnice, near Brno, in the Miocene of the Carpathian foreland. The known reserves here amount to several hundred thousand tons, but the possibility of exploiting them commercially at the present time seems doubtful.

Petroleum in Bahrein Island in 1937*

The oil production in Bahrein for the year 1937 was 7,762,264 bbl., a monthly average of 646,855 barrels.

Sufficient potential production had been developed in the Second Pay (Main Pay) at Bahrein by the end of 1936 to supply the anticipated crude demand, and the drilling program was changed from straight development to partial exploration during 1937. Two nonproductive wells were drilled to test the Third Pay at a depth of about 2900 ft., or some 900 ft. below the top of Second Pay. As a result of this exploratory work, the normal drilling program was slowed down and only eight new wells were completed in the Second Pay during 1937, making a total of 45 producers from the Second Pay.

The deep test was drilling at 5081 ft. at the end of the year. A 550-ft. section (termed Fourth Pay) of porous limestone interbedded with anhydrite was topped at about 4150 ft. Numerous drill-stem tests indicated that the limestone was very permeable and that it carried large volumes of natural gas under high pressure together with a small amount of high-gravity oil or condensate. Drill-stem tests also indicated that the bottom 50 ft. of the 550-ft. section carried an encouraging amount of heavier oil, gravity about 37° A.P.I., with characteristics similar to the oil produced from the Second Pay. A well was started somewhat downstructure from the deep test to better determine the oil-producing possibilities of the Fourth Pay.

Some refinements in drilling technique were adopted during the year. All wells started to the Second Pay were drilled with rotary from the surface. The top 1500 ft. of porous limestone section, formerly drilled with cable tools, is now drilled with rotary without circulation, using water to wash the cuttings into cavities. The shale section from this point to the top of the oil horizons is drilled with natural mud circulation. The productive horizons are drilled with oil circulation under pressure control. A second satisfactory method of completing wells was developed when the two Third Pay test wells were plugged back and gun-perforated through cemented casing opposite the Second Pay, with good results.

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* Information received through the courtesy of the Bahrein Petroleum Company Ltd. Manuscript received at the office of the Institute April 18, 1938.

Development of the Petroleum Industry in Bolivia in 1937

By Jorge Munoz Reyes* and Guillermo Mariaca†

The new entity, Yacimientos Petroliferos Fiscales Bolivianos, created in 1936 for the development and exploitation of all petroliferous zones of Bolivia, including those formerly belonging to the Standard Oil Co., is doing its utmost to bring about rapid development and by this means to create a new source of revenue for the State.

With this in view, Y.P.F.B. has opened a new field in the Samaipata region, on the main road between Cochabamba and Santa Cruz. Installation of machinery has begun for the drilling of several wells on the five anticlines that occur in this region. Work has also begun in the Saipuru field, on the Santa Cruz-Charagua highway, which was discovered by the Standard Oil and temporarily abandoned. In this new field, a topping plant will be installed, to supply gasoline and kerosene to Santa Cruz. Explorations are also being made on the neighboring structures of Saipuru.

At the end of 1937, the committee that is to study the region of the Chapare in the northeastern part of Cochabamba, was organized. The structures were studied 10 years ago by Kirtley Mather and other geologists. It is hoped that by March 1938 this camp will begin work, as this zone gives promise of being valuable.

DEVELOPMENT

The capacity of the refinery at Camiri has been enlarged in order that it may supply all the needs of that region. In order that the supply of crude may be adequate, several wells that had been almost abandoned by the Standard Oil are being cleaned out. New wells have been located at this camp following the principal anticlinal structure, and during the first half of the year 1938 several wells will be drilled.

The same program is being followed in Sanandita but on a greater scale, as the nearness of this district to the Argentine border, which is the best market for the Bolivian petroleum of the south, allows immediate sale of the petroleum. Possibly a new refinery will be installed at this camp, as the one now in existence is only a rudimentary distillery.

At the Bermejo camp, which is farther south, intensive work is being done to bring the wells into production. The Standard Oil produced limited quantities several years ago, but since 1927 the wells of this dis-

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* Yacimientos Petroliferous Fiscales Bolivianos, La Paz, Bolivia.

† Direcion General de Minas y Petróleos, La Paz, Bolivia.

trict have been closed and the camp nearly abandoned. It is possible that a 6-in. pipe line will be built between camp Bermejo and the neighboring town of Oran, which is the terminal point of an important railway.

The cost of transportation of gasoline and other products of petroleum from Camiri and Sanandita to the western markets of Bolivia has been high because transportation has all been by tank wagon. An agreement has been made with the Argentine Republic for railroad transit, which will lessen the cost of transportation and so cheapen petroleum products when sold in the markets of the high plateau. This transit agreement is one of the best proofs of the good will that now exists. Also, agreements have been made for the sale of Bolivian petroleum in North Argentina and for the interchange of products.

Cooperation with Brazil and Chile

About the middle of 1937, the Brazilian Republic sent a delegation of technical men, headed by the Chief of the Bureau of Mineral Production of Brazil, to Bolivia to study the possibility of developing petroliferous fields in this country, from which all or the majority of the production would be for the Brazilian market. The delegation remained in Bolivia for three months and studied especially the eastern foothill belt of the Andes.

As a result of the visit of this delegation, treaties have been signed which tend to the development of the petroleum and railroad industries so that the relations of the two countries may be strengthened. The sum of a million and a half dollars will be spent in exploration work in the region between Parapeti River and River Ichilo, and an ample plan for drilling will be worked out. If production justifies it, a pipe line will be built so that this petroleum may be taken into Brazil, where it will be refined and sold. A program for the creation of companies with part public and part private capital has been laid out, the companies always to be supervised by Yacimientos Petroliferos Fiscales Bolivianos.

The Brazilian-Bolivian delegation made extensive studies of the Sub-Andean region and also of a new region called "Chiquitana" which is situated on the eastern plains between Santa Cruz and the Paraguay River, including the range of San Jose and Santiago in the Provinces of Ñuflo de Chavez, Velasco and Chiquitos. At the beginning of 1938 the permanent commission, composed of technical men from both countries, must start its detailed study of the geology of the Sub-Andean and Chiquitana regions.

In order to reduce the cost and the price of sale of petroleum products in the western markets of Bolivia, which are at present the most important of the country, a plan for building a big refinery on the high plateau, possibly in the town of Challapata, is being contemplated. Crude oil would be transported by railroad to the refinery.

Chilean and Bolivian authorities have explored the district of Pacajes, on the Mauri River, and will continue to do so in 1938, to see whether there is any possibility of commercial production, for sale mostly in the Chilean markets and in southern Peru, besides providing at a low cost for the mining centers of the high plateau.

OUTLOOK

It may be said that Bolivia is just starting an era of intense development in petroleum production, since in the last 16 years no steps were taken to develop this industry, which constitutes a source of wealth for the country and which will in the near future occupy a predominant place in the economy of the country, the place that now is occupied by the tin industry.

PRODUCTION

During the year 1937, production was as follows: crude oil, 19,587,718 liters (123,193 bbl.); gasoline, 10,264,217 liters (64,555 bbl.); aviation gasoline, 227,836 liters (1,433 bbl.); kerosene, 346,532 liters (2,179 bbl.); fuel oil, 8,465,938 (53,244 bbl.).

Oil-field Development in Burma and India

By L. Dudley Stamp*

On April 1, 1937, Burma, formerly a province of the Indian Empire, was formally separated from India and became an independent unit of the British Commonwealth. In future, therefore, statistics of oil production in India will exclude Burma and those for Burma will be separately published.

The last few years have been marked by noteworthy, almost spectacular, developments in the oil fields of Burma and the Punjab. In Burma these developments have been the proving of unexpected extensions of the existing fields and not the discovery of entirely new fields. The new extensions are important not only to Burma in giving a new lease of life to her fields, but also in general as stressing some interesting geological aspects hitherto neglected.

PRODUCTION

The production of crude oil in Imperial gallons has been:

	Burma	India
1934	254,760,070	67,265,210
1935	251,338,974	71,323,362
1936	265,656,393	69,241,504
1937 (est.)	270,000,000	70,000,000

The Chindwin Fields.—The small field at Indaw continues to produce steadily about 3,000,000 gal. a year, but no really deep test has yet been successfully carried out and resources are thus not yet fully known. The remote location of the field, inaccessible except by river and situated 22 miles from the Chindwin 270 miles up that river from its junction with the Irrawaddy, has not encouraged active exploitation. The field is worked exclusively by the Indo-Burma Petroleum Co., Ltd. (I.B.P.), using now an automatic gas-lift system, and the company formerly refined the oil at a small refinery at Pantha on the river near by. The chief market was for kerosene in upper Burma. The refinery has now been closed. The oil is stored on the field during the low-water season

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(when the main channel of the Chindwin has a depth of as little as 2 ft. 6 in. in places) and sent down by oil flat in the high-water season, to the company's main refinery near Rangoon.

The Burmah Oil Company (B.O.C.) is carrying out a deep test at Yenan, near Yuwa, on the western side of the Chindwin. Farther south on the eastern side of the Chindwin at Palusawa, the I.B.P. testing of a faulted dome has been temporarily abandoned.

Yenangyat-Lanywa-Singu Fields.—This long line of fields is associated with one long anticline of Peguan rocks stretching some 50 miles from north to south. The fold is like most in similar situations in Burma, asymmetric with a gentle limb on the west and a vertical or slightly overfolded limb on the east. Towards the south the river Irrawaddy cuts across the fold obliquely from northeast to southwest so that the northern group of fields is in the Pakokku district, the southern group in Magwe.

Toward the northern end the fold is deeply dissected, and most of the oil-bearing horizons of the south have been denuded away. The small old Sabé field occupies a local crest maximum, the centrally placed Yenangyat field occupies another local crest maximum and has been the scene of recent drilling activity and increased production, mainly by the B.O.C. and the B.B.P.

Near the village of Lanywa, on the right bank of the Irrawaddy, the I.B.P. many years ago drilled five wells actually on the banks of the river. A somewhat irregular production from three of them led the company to believe that the Singu field extended under the main bed of the river. Accordingly, the company obtained Government sanction to build a wall and so enclose a large sandbank formerly exposed only in the low-water season. On this sandbank is now situated the famous model field of Lanywa. The wall, built of local stone and brick, is now 11,500 ft. long, and 90 wells have been drilled, of which 80 are now producing (February 1938). The initial production from some wells may be as much as 600 bbl. per day, but the total offtake is controlled according to the requirements of the company's refineries near Rangoon. In 1937 it was about 17,000,000 gal. The field is entirely electrified, current being generated by gas engines using gas from the field on the spot. Most of the wells are pumped in pairs continuously. The oil is sent by river to the refineries near Rangoon. The company has also the rights over the oil under the bed of the river, the river channel still being 3000 ft. wide. A scheme to mine this oil has been under consideration for some time, but obviously oblique drilling is another solution of the problem and is now being tried out.

Singu, or Chauk, is still the main reserve of the B.O.C. outside Yenangyaung, and is on the left bank of the river facing Lanywa. Production is controlled according to the needs of the refineries and development is still limited. The B.O.C. has, however, followed a policy of offsetting or of intensive development along the margins of its property. Thus, following the success of the Lanywa wall, the B.O.C. constructed a wall along the margin of its concession 660 ft. from the old river bank, and now has a closely spaced line of wells actually along the crest of the wall. Farther south, just beyond the western margin of the B.O.C. concession, oil was obtained some years ago by the Hessford Development Syndicate, and again offsetting was practiced. The Development Syndicate eventually sold its rights to the B.O.C.

Down the steep southern pitch of the Singu fold an extensive pool was located and developed by the British Burmah Petroleum (B.B.P.) and Rangoon Oil Companies. This Negya field was, at the time, unexpected, but in richness has now been far exceeded by a new pool still farther down the pitch. A normal fault with a very low hade crosses the fold approximately from east to west and has sealed off a large field to the south. This is now worked jointly by the I.B.P. and B.B.P. (operating as the Pyinma Development Co., Ltd.) which have now (February 1938) 24 wells over a proved area of some 200 acres. The oil is largely from one sand (the Moola oil sand) at between 400 and 500 ft. but the whole extent of the new pool is by no means yet known. Along the eastern margin—that is, roughly long the crest of the fold—the Moola Oil Co. has also practiced offsetting and has a double line of wells (41 in all, February 1938). All are, however, small producers. The drilling for this native company is carried out by the Burmah Oil Co., which also purchases the oil produced. The new field as a whole illustrates the great importance of cross faulting in sealing off the fields into separate blocks. The whole Singu field has been electrified, the power being brought from the B.O.C. power station at Yenangyaung and sold to the various operating companies.

Yenangyaung.—This famous oil field, fully considered in previous years, has produced continously from machine wells for 50 years. The recognition of a slight asymmetry of the fold and the consequent successful testing of a large eastern extension has almost doubled the proved area of the field and so added greatly to its life. As in Singu, southern pools sealed off from the main field by cross faulting have been proved but do not appear as rich as at Singu.

The main part of the Yenangyaung field is in the concessions of the B.O.C. but in the midst two small areas—the Bemé and Twingôn reserves—were set aside for the benefit of the Twinzayos—hereditary Burmese owners. The owners were allowed to sell the well sites and so the reserves have been the scene of fierce competitive drilling, so that now practically no well sites remain. There are still a few Burmese hand-dug wells remaining.

The whole of the Yenangyaung field has been electrified in the last 10 years from the central B.O.C. power plant at Ngaunghla (on the Irrawaddy just southwest of the field). The B.O.C. wells are now pumped in groups of 80 or 90 by band-wheel central pumping powers and the power is sold to the other operating companies for pumping purposes. The consequent changes in the field are still taking place. Instead of being noisy with steam engines, the whole field is now almost silent. The old wooden rigs are disappearing, their place being taken by simple tripods, while all new rigs are of standard steel type. Thus the whole field appears much less congested than formerly and there is a great economy in labor.

The new eastern extension of the main field has been successfully tested and exploited to depths up to 8000 ft. The new southern pool is worked mainly by the B.B.P.; it has been moderately successful but does not seem to have reserves as large as the new field at the south end of Singu. The I.B.P., and Natsingh Oil Co. also operate at Yenangyaung. The latter has a small refinery at Ngaunghla, the B.O.C. oil is sent by pipe line to the refineries at Syriam (Rangoon), and the other companies ship their oil by oil flat on the river.

Minbu, Yethaya and Palanyôn.—There is little to record regarding the three small fields along the Minbu fold of Peguan rocks. A refinery has been erected by an independent company at Yethaya (the Upper Burma Refinery Co. Ltd.).

Yenanma and Padaukpin.—The Indo-Burma Oilfields (1920) Ltd., which worked these fields (Padaukpin in conjunction with the Premier Oil Co., Ltd.) has gone into liquidation, but the fields are still worked by the liquidators (Fortescue Brothers). The production from the shallow wells (300 to 500 ft.) of the Yenanma homocline or monocline is about 200 bbl. a day, and the operation is a profitable one.

Monatkôn.—The B.O.C. test on this dome in the Thayetmyo district reached 8200 ft. It was the deepest test in Burma, but failed to find any oil.

Pyayé.—The first well on this structure tapped an enormous gas sand, which blew wild for a number of months (yielding between 20,000,000 and 30,000,000 cu. ft. of gas per day). Eventually it was closed in. In 1936–1937 the gas was piped to Thayetmyo and used as fuel for a new venture, the Burma Cement Co. Ltd., which uses limestone from a near-by hill and has now a considerable and successful output of cement of good quality. The fuel used is about 2,000,000 cu. ft. per day. The I.B.P., which controls the field, is now (February 1938) starting a deep test for oil at Pyayé.

The Punjab.—The most remarkable development in India in recent years has been in the Punjab. The Attock Oil Co. Ltd. continues to exploit its successful though disappointing field at Khaur and also tested the open dome of Dhulian a few miles to the southwest. The test resulted in the discovery of a fine field in limestone; the first well came in at over 600 bbl. a day, and two wells provide all the oil the company can handle at present.

Petroleum and Natural Gas in Canada during 1937

By G. S. Hume*

(New York Meeting, February, 1938)

As predicted a year ago, owing to the discovery in 1936 of crude oil on the west flank of the south end of Turner Valley in the eastern foothills of Alberta, 50 miles southwest of Calgary, and the drilling activity that resulted, the production of crude oil in Canada during 1937 showed a very substantial increase over the previous year. The production from other parts of Canada is relatively small and shows slight variations only from year to year. The production of crude oil in Canada and the production in Alberta, the main producing Province, is shown in Tables 1 and 2.

Table 1.—*Production of Petroleum in Canada*
Barrels of 35 Imperial Gallons = 42 U. S. Gallons

Province	1936	1937[a]
Alberta	1,310,000	2,796,908
Ontario	165,495	164,197
New Brunswick	17,112	22,549
Northwest Territories	5,399	11,371
Total	1,498,006	2,995,025

[a] Production estimated by Mining, Metallurgical and Chemical Branch, Bureau of Statistics, Ottawa.

Table 2.—*Production of Petroleum in Alberta*

Field	1936	1937
Turner Valley	1,278,000	2,767,221
Red Coulee-Border	17,000	13,790
Wainwright	14,700	14,697
Skiff	300	
Taber		600
Moose		600
Total	1,310,000	2,995,025

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* Geologist, Geological Survey of Canada, Ottawa, Ont.

Proration.—These production figures, however, give a very incomplete history of developments because the oil supply in Turner Valley increased so rapidly in the late summer of 1937 that pipe lines and market facilities could not be adjusted to the new conditions with sufficient rapidity to take care of the whole production. The result was that the major refining companies, through whom most of the supply is marketed, were forced to inaugurate proration. The first proration of 65 per cent of potential yield was put into effect on Sept. 12. On Nov. 1 this was decreased to 45 per cent and on Nov. 15 again decreased, to 35 per cent. It remained at 35 per cent to the end of the year when it was increased to 42 per cent as adjustments in marketing were made. In December 1937 and in January 1938 tests made by the Alberta Department of Lands and Mines showed a daily potential crude-oil production in Turner Valley of 26,803 bbl., an amount sufficient to take care of the needs of the whole of the prairie provinces of Canada. This production comes from 35 wells, 25 of which were drilled and finished as crude-oil wells in 1937. Seven of these 35 wells originally were finished as naphtha-gas wells but in the course of time the product yielded by them gradually became heavier and is now crude oil. In each of these wells, however, the production is relatively small in comparison with that of the wells finished within the crude-oil area.

Acid Treatment.—Production has been greatly augmented in Turner Valley by the use of acid. The productive reservoir rock is Palaeozoic limestone and dolomite and in the wells 5,000 to 10,000 gal. of 15 per cent hydrochloric acid have been used. The effect of acidization is illustrated by Turner Valley Royalties well, completed in June 1936 with a flow of 850 bbl. of 44° A.P.I. oil a day. In June 1937, when the production had dropped to 550 bbl. a day, the well was acidized. The average daily production for July 1937 was 1203 bbl., and at the end of 1937 the potential of this well as measured by the Alberta Department of Lands and Mines was 1221 bbl. a day, the potential being based on five days average production.

Size of Area.—The proven crude-oil area on the western flank of southern Turner Valley is now 3 miles long by ¾ mile wide. There is no doubt that drilling will greatly extend this area, as the production limits are so far not defined to the south, north or west. On the east the higher parts of the structure contain gas. One of the remarkable features of Turner Valley is the amount of closure within the producing area. This now amounts to 3718 ft. on the top of the Palaeozoic limestone and no edge water has been encountered. There is a strong probability that oil occurs at a considerably greater depth down the west flank.

Deep Wells.—The deepest well in the crude-oil area is 7475 ft. and the shallowest 6060 feet. East of Turner Valley and west of the town of

High River, Alberta, a well reported as having reached a depth of 8750 ft. at the end of 1936 was finished in 1937 at a depth of 8988 ft., where water was encountered. This well is in the Alberta syncline, a broad downwarp east of the foothills.

Taber and Ribstone Fields.—At Taber, in southern Alberta, a crude-oil area was discovered by the Plains Petroleum Co. In the discovery well some water troubles developed. The gravity of the oil is 27.5° A.P.I. Three wells have been drilled. The Ribstone field in eastern central Alberta has been reopened after several years of inactivity. The oil in this field is heavy but occurs at less than 2000 ft. in depth in Lower Cretaceous strata. To the west of the Ribstone area and east of the Wainwright, a well was drilled on the Battleview structure, discovered by the Geological Survey of Canada in 1935. The well showed a saturated oil core and gave a large flow of gas. At present it is closed in. The productive horizon occurred in Lower Cretaceous strata at a depth of 1893 feet.

GAS

The gas produced in Canada is shown in Table 3. Turner Valley continues to be the main source for all gas used in Calgary and in centers of population adjoining the Calgary-Foremost pipe line. The peak load of gas used in Calgary in the winter months is about 60,000 M cu. ft. a day but in summer the consumption is much less. The Bow Island gas field of southern Alberta was approaching exhaustion in 1930 when repressuring operations were begun with excess Turner Valley gas. Up to July 31, 1937, almost ten billion cubic feet of gas had been forced back into the field, and the pressure increased from 248 to 542 lb. Repressuring operations are still being continued. A few shallow wells near the town of Brooks continue to supply gas for this town. At Medicine Hat, the gas field is partly owned by the city and after 33 years of continuous operation is still a very important producer.

TABLE 3.—*Production of Natural Gas in Canada*
THOUSANDS OF CUBIC FEET

Province	1936	1937
Alberta	16,650,000	17,058,439
Saskatchewan	90,312	92,528
Manitoba	600	600
Ontario	10,016,444	10,190,334
New Brunswick	606,246	576,629
Total	27,363,602	27,918,530

The Viking gas field, 70 miles east of Edmonton, continues to be the main source of supply for that city. To the east of Viking a small field at Fabyan supplies gas for the town of Wainwright.

At Lloydminster, Saskatchewan, close to the Alberta border, some further drilling for gas was done during the year. The supply is being used only in the town of Lloydminster.

In Ontario drilling for gas in the peninsula between lakes Huron, Erie and Ontario continues to meet with considerable success. In Raleigh township, Kent County, one well at a depth of 1536 ft. encountered 17,000 M cu. ft. in the top of the Guelph (Silurian) formation. Two wells in Dereham township, Oxford County encountered more than 20,000 M cu. ft. each in the same horizon at 939 ft. Numerous other smaller gas wells were successfully completed. In the old Petrolia field, one of the early oil fields opened in Canada in 1865, a well was drilled to the pre-Cambrian granite, which was encountered at a depth of 4120 ft. No production was found below the main producing horizon, which still continues to yield oil in this field after 72 years of continuous operation.

Petroleum Developments in Colombia during 1937

By O. C. Wheeler,* Member A.I.M.E.

(New York Meeting, February, 1938)

The activity in exploration and in the acquisition of prospective oil lands that reached such a high level in Colombia during 1936 gained momentum and reached unprecedented proportions during 1937. Both national and private lands were taken up.

In the Magdalena Valley above Puerto Berrio, leases on large tracts of private lands are held by Richmond (Standard of California), Shell and Texas. Tropical also owns leases covering a block of acreage in this area near Honda. From Puerto Berrio to El Banco most of the acreage is of national ownership, and concessions covering parts of this area have been granted to Tropical, Socony Vacuum, Shell and others, while applications for additional concessions are pending. Latterly leases on private lands below the Lebrija River have been taken out by Shell and Richmond.

In the drainage basins of the Meta and Guaviare Rivers of the Llanos region of eastern Colombia, several of the major companies have carried on geological exploration and it is understood that some private properties have been leased or optioned.

Under Colombian law, subsoil rights are reserved to the nation on all lands that passed from Government ownership after Oct. 28, 1873. Private titles antedating that day carry both surface and subsurface rights. Conditions under which lands may be acquired, explored and

Table 1.—*Oil and Gas Production in Colombia*

Line Number	Field, *County*	Age, Years to End of 1937	Total Oil Production, Bbl.			
			To End of 1937	During 1936	During 1937	Daily Average during Nov. 1937
1	Infantas, *Santander*	19	112,735,748	6,364,429	6,481,173	17,829
2	La Cira, *Santander*	11	93,385,745	12,391,680	13,816,673	41,665
3	Las Monas, *Santander*	10				
4	Petrolea, *Santander del Norte*	5				
5	Rio de Oro, *Santander del Norte*	17				

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* Chief Geologist, International Petroleum Co. Ltd., Toronto, Canada.

developed for their oil resources are given under Law 37 and its Regulating Decree No. 1270 both of 1931, and by Law 160 of 1936 and its Regulating Decree No. 950 of 1937.

The status of applications of various companies for concessions on national lands, as reported by the Ministry of Industries, is shown in Table 2.

OPERATING COMPANIES

Colombian Petroleum Company.—During the year 1937 seven wells were completed on the Barco Concession—four at Petrolea and three in the Rio de Oro area. Of the Petrolea wells, three were completed as producers with a total initial production of about 2400 bbl., and one was a dry hole. Of the three wells in the Rio de Oro area, two were producers with a total initial production of 4000 bbl., and one was a dry hole. To date there are 12 producing wells in the Petrolea field, varying in depth from 650 to 1650 ft. In the Rio de Oro area there are three producers with depths from 1300 to 1650 feet.

TABLE 1.—(*Continued*)

Line Number	Number of Oil and/or Gas Wells			Depth, Average in Feet		Oil Production Methods at End of 1937				
	Completed to End of 1937	During 1937		Bottoms of Productive Wells	To Top of Productive Zone	Number of Wells				Injection into Reservoir[c]
		Completed	Abandoned			Flowing	Pumping	Gas-lift	Air-lift	
1	452	0	1	1,000–2,600	400–2,200	72	493	1	0	32
2	390	65	0	600–4,294	400–3,950					
3	10	1	0							
4										
5										

Line Number	Character of Oil, Approx. Average during 1937					Character of Gas, Approx. Average during 1937	Producing Rock						Number of Dry and/or Near-dry Holes to End of 1937	Deepest Zone Tested to End of 1937	
	Gravity A.P.I. at 60° F.			Sulphur, Per Cent	Base[e]	B.t.u. per Cu. Ft.	Name	Age[f]	Character[g]	Porosity[h]	Net Thickness, Average in Feet	Structure[i]		Name	Depth of Hole, Ft.
	Maximum	Minimum	Weighted Average												
1	35	23	26.1	0.90	A	1,050	A, B and C zones	Oli-Eoc	S	15–22	50–200	AF	15	Cre	4,048
2	27	20	23.5	0.90	A	1,050	A, B and C zones	Oli-Eoc	S	15–25	50–175	AF	1	Cre	3,536
3					A			Eoc	S			AF	4	Cre	5,434
4												A		CreL	
5												A		CreL	6,717

[e] Footnotes to table heads and explanation of symbols are given on page 313.

Socony Vacuum Oil Co.—The Socony Vacuum Oil Co. holds concessions between the Rio Sogamoso and the Rio Lebrija. During 1937 it continued its geological and geophysical exploratory program. In addition, it completed one fuel-oil well and was drilling a second. The location for a deep test has been selected on the Restrepo Concession and will be drilled during 1938 with a modern Diesel rig.

TABLE 2.—*Status of Applications*

Company	District	Date Accepted	Area, Hectares
APPLICATIONS ACCEPTED IN 1937 BUT CONCESSIONS NOT YET GRANTED			
Consorcio Minero Nacional.......	Carare-Ermitano	Feb. 1	44,258
Sindicato de Inversiones S. A......	Lebrija River	June 4	45,905
Compania de Petroleo Shell de Col..	Carare River	Mar. 18	49,906
Compania Colombiana de Petroleo El Condor....................	Cimitarra River	Aug. 3	47,810
APPLICATIONS ACCEPTED IN 1936 BUT CONCESSIONS NOT YET GRANTED			
Cia de Petroleo del Carare.......	Lebrija River	Dec.	49,636
Socony Vacuum Oil Co. of Colombia	Sogamoso River	Sept. 1	27,040
Daniel del Rio..................	Galerazamba, Altantico	Sept. 25	20,141
NATIONAL CONCESSIONS AWARDED 1931 TO 1937 UNDER LAWS 37 AND 160			
		Date Awarded	
Tropical Oil.....................	Putana (Sogamoso)	Mar. 1, 1933	7,430
Sociedad Nacional del Carare (under joint exploration with Tropical).....................	Carare	Sept. 22, 1936	33,476
Mora Concession (transferred to Shell, Oct. 27, 1937)...........	Carare	Sept. 28, 1937	50,000
L. Restrepo Concession (transferred to Socony Vacuum)............	Sogamoso		49,232

Tropical Oil Co.—Operations on the Tropical Oil Company's De Mares concession reached the highest level since 1930. Seventy wells were completed, of which 65 were commercial producers and yielded an average of 508 bbl. initial. Production from the Infantas and La Cira fields totaled 20,297,846 bbl., of which 243,388 bbl. was petroleum condensate added to crude. Drilling was continued on the Putana concession, which is a relatively small tract of national lands within the boundaries of the De Mares property. Well No. 3 on this property had reached a depth of 6560 ft. at the end of the year and was still drilling.

Petroleum Production in Cuba in 1937

By Roy E. Dickerson,* Member A.I.M.E.

(New York Meeting, February, 1938)

No important new developments took place during the year 1937 in Cuba. Estimated figures are as follows: Bacuranao field, 100 bbl. per day petroleum; Motembo and Vesubio areas, 120 bbl. per day natural gasoline.

Manuscript received at the office of the Institute Feb. 2, 1938.

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Production of Oil in Egypt in 1937*

THE following table summarizes the information on the Hurghada field, which is still the major producing field in Egypt.

HURGHADA FIELD

Age of field to end of 1937, years	24
Producing area for gas and oil, acres	1,050
	BARRELS[1]
Total oil production to end of 1937	30,188,500
Total oil production during 1936	1,219,406
Total oil production during 1937	1,141,230
Average oil production per acre to end of 1937	28,750
Average oil production per acre-foot to end of 1937	2,359
Daily average production (Nov. 1937)	3,162
Daily average production per well (Nov. 1937)	41.88
	MILLIONS CU. FT.
Total gas production (Aug. 1925 to end of 1937)	4,189
Total gas production during 1936	281
Total gas production during 1937	222.5
Maximum daily average in 1937 (July)	0.7
Number of producing wells completed to end of 1937	97
Number of producing wells completed during 1937	3
Number of wells abandoned during 1937	1
Producing wells at end of 1937	78[2]
Total number abandoned wells at end of 1937	19
Total number dry wells at end of 1937	20
Average depth of bottom of producing horizon, ft	1,720
Average depth of top of producing horizon, ft	1,598

Character of oil, approximate average in 1937: gravity at 60° F., 0.900; base, mixed.

Character of gas, approximate average during 1937: gallons gasoline per 1,000 cu. ft., 6.9.

Producing rock (main): Nubian(?) sandstone, Cretaceous(?); character, sand rock and sandstone.

[1] Figures were given in E. tons. A conversion factor of 6.98, based on 0.900 sp. gr., was used to obtain the number of barrels.—Ed.

[2] All pumping.

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* Information received through the courtesy of the Controller of the Egyptian Department of Mines and Quarries, Dawawin P. O., Egypt. Figures received Feb. 16, 1938.

Petroleum Research in France and in the French Colonies during 1937

By H. de Cizancourt*

France.—Pechelbronn remains about the only producing field, 41 per cent of the 1937 output of 496,525 bbl. being mined by shaft and 59 per cent produced from pumping wells. At present Gabian has only a very small production. During 1937 there was no private undertaking for petroleum research. Only the Office National des Combustibles Liquides has done any drilling, unsuccessfully, at Pezenas and Frangy-Chilly.

Algeria.—No new research has been made and Tliouanet, a small acreage pool that has been declining for several years, gave only 2193 bbl. in 1937.

Morocco.—The Société Chérifienne des Pétroles continues active work. First tests of production made on the Jurassic structures of the Tselfat and Bou Draa must be mentioned for 1937. In connection with these tests, which have yielded 16,495 bbl., 14 new wells have been located

Table 1.—*Oil and Gas Production in France and French Colonies*

Line Number	Field, *Department*	Age, Years to End of 1937	Area Proved, Acres		Total Oil Production, Bbl.				Number of Oil and/or Gas Wells				
			Oil	Total	To End of 1937	During 1936	During 1937	Daily Average during Nov. 1937	Completed to End of 1937	During 1937		At End of 1937	
										Completed	Abandoned	Producing Oil Only	Total Producing
	France:												
1	Pechelbronn, *Bas Rhin*	202	7,575	7,575	15,444,437	484,453	496,525		about 4,000	63	39	622	622
2	Gabian, *Hérault*	13			160,664	2,893	2,650						
	Algeria:												
3	Tliouanet, *Oran*	26	30		198,270	2,297	2,193						
	Morocco:												
4	Tselfat (16 km. east Petitjean)	1	20		12,295		12,295		13	5		7	
5	Bon Draa (3 km. east Petitjean)	1	55		4,200		4,200		16	8		8	8

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* Compagnie Française des Pétroles, Paris, France.

in these two pools, among which are 10 producers. Three rigs were still drilling at the end of December. Exploration has not proved any new pool, but wildcats have added to the knowledge of the structure of that region and of the basement of the Jurassic limestone. In the whole three wildcats have been completed and four were drilling at the end of December 1937.

Tunisia.—Two wells were drilling by the end of the year; one, in Djebel Zaouia, is a first test of the Central Tunisia structures, the other, in Roazouane, is a geological test.

Madagascar.—The Tsimororo structure has been tested by a second wildcat, which has shown indications of very thick oil not in commercial quantity.

Afrique Equatoriale Française.—Field geological studies must be proved by drilling. The Kongo I drilled during 1937 has proved the formations of the Upper and Middle Cretaceous.

TABLE 1.—(*Continued*)

	Depth, Average in Feet	Oil Production Methods at End of 1937			Character of Oil, Approx. Average during 1937					Producing Rock						Deepest Zone Tested to End of 1937	
		Number of Wells			Gravity A.P.I. at 60° F.												
Line Number	Bottoms of Productive Wells	Flowing	Pumping	Bailing	Maximum	Minimum	Weighted Average	Sulphur, Per Cent	Base[e]	Age[f]	Character[g]	Porosity[h]	Net Thickness, Average in Feet	Structure[i]	Number of Dry and/or Near-dry Holes to End of 1937	Name	Depth of Hole, Ft.
1	1,310–3,065		622		17.5	39	27.5	0.7	PM	Oligocene Jurassic Trias	SOD	Variable		AF	22	Lower Trias	4,590
2																	
3																	
4	700–900	3								Jurassic (middle Domerien)	LO	Fis		AF		Jurassic	6,437
5	600–650			3						Jurassic (middle Toarcien)	L			AF			

[e] Footnotes to table heads and explanation of symbols are given on page 313.

TABLE 2.—*Summary of Drilling Operations in France and French Colonies*

Important Wildcats Drilled in 1937

	Country	Location	Total Depth, Ft.
	France:		
1	Pézenas	Department of Hérault	2750
2	Frangy-Chilly	Department of Savoie	1488
	Morocco:		
3	Bab Tisra 3	3 km. (1.8 miles) south of Petitjean	5868
4	Oulja 1	7 km. (4.4 miles) ESE. Petitjean	7062
5	Gueddara 1	8 km. (4.9 miles) SE. Tselfat	7321
6	Outita 6	8 km. (4.9 miles) SW. Petitjean	2773
7	Slafta 1	1.5 km. (0.9 miles) W. Tselfat	3362
	Tunisia:		
8	Kef bou Debbous	9 km. (5.6 miles) NNE. Teboursouk	4262
9	Djebel Kebir 1	4 km. (2.5 miles) NW. Bizerte	3635
10	Djebel Zaonia	50 km. (31 miles) SW Kaisouan	1650
	French Equatorial Africa:		
11	Kongo 1	1° 32′ S, 9° 29′ E	2813
	Madagascar:		
12	Tsimiroro 1	18° 21′ S, 42° 40′ E	3000
13	Tsimiroro 2	12½ ft. SW. Tsimiroro 1	7460

Important Wildcats Drilled in 1937

	Surface Formation	Deepest Horizon Tested	Drilled by	Remarks
1	Cretaceous (lower Rognacien)	Jurassic	Office National Combustibles Liquides	Drilling end 1937. Oil shows between 2678 and 2695 ft.
2	Miocene	Miocene	Office National Combustibles Liquides	Abandonned on account of mechanical difficulties
3	Upper Toarcian	Triassic (?)	Société Cherifienne des Petroles	Geological test
4	Upper Cretaceous	Jurassic (Domerian)	Société Cherifienne des Petroles	Dry hole
5	Upper Cretaceous	Jurassic (Toarcian)	Société Cherifienne des Petroles	Still drilling
6	Upper Toarcian	Jurassic (Domerian)	Société Cherifienne des Petroles	Dry hole
7	Bajocian	Jurassic (lower Toarcian)	Société Cherifienne des Petroles	12 bbl. per day bailed in middle Toarcian
8	Upper Cretaceous	Lower Cretaceous	Syndicat d'études et des recherches petrolières	Dry hole
9	Paleocene	Upper Cretaceous		Gas outburst
10	Lower Cenomanian			Drilling end 1937
11	Upper Cretaceous	Lower Cretaceous	Syndicat d'etudes et se recherches petroliens	Geological test
12	Upper Triassic—Lower Liassic (oldest Jurassic)		Syndicat d'etude et se recherches petroliens	
13				Shows of very heavy oil

	In Proven Fields	Wildcats
Number of wells drilling Dec 31, 1937	3	7
Number of oil wells completed during 1937	10	7
Number of gas wells completed during 1937		
Number of dry holes completed during 1937	4	8

Petroleum Developments in Germany during 1937

By Walter Kauenhowen*

Germany's crude-oil production during 1937 totaled 3,174,157 bbl., an increase of 1.9 per cent over the 3,112,494 bbl. produced in 1936.

According to official published data, and using a conversion factor of 1 metric ton = 7 bbl., the oil production of Germany in 1937 by fields was as follows:

Field	Production, Bbl.	Percentage of Total Production
Nienhagen	2,427,677	76.5
Wietze	313,383	9.9
Oberg	149,870	4.7
All other fields	283,227	8.9
Total	3,174,157	100.0

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* Deutsche Vacuum Oel A. G., Hamburg, Germany.

Search for Oil in Great Britain

By A. H. Taitt*

(New York Meeting, February, 1938)

The original basis for the search for oil in Great Britain was described last year.† During 1937 the exploratory drilling by the D'Arcy Exploration Company, Ltd. has been continued. Three wells have been completed in the south of England and a fourth is nearing completion. In addition, test wells are now being drilled in Scotland and East Yorkshire.

Southern England

The test well on the Portsdown structure, which at the end of 1936 was drilling in the Lower Lias at 5792 ft., entered the Triassic at 6540 ft. and was completed in that formation at a depth of 6556 ft., without encountering further indications of petroleum.

The Henfield well encountered the Lias at a depth of approximately 4090 ft., and after drilling 800 ft. of an argillaceous development of that formation entered a series of marls, breccias and conglomeratic limestones of the Carboniferous. Drilling was suspended at a depth of 5105 ft., in the latter formation.

The consistently impermeable nature of the strata encountered in the Portsdown and Henfield test wells focused attention on the desirability of obtaining shore-line conditions of the Jurassic. With this end in view the Kingsclere anticline, a few miles south of Newbury in Berkshire, was selected for a next test. The Kingsclere well has now reached a depth of 5032 ft. in the Lower Lias and has encountered a full development of the Jurassic. With the exception of the Portland sand, which has a slightly greater porosity, and the Corallian, in which relatively great thicknesses of impervious limestone were met, conditions of sedimentation have been found to be comparable with those of the earlier wells.

Small traces of petroleum have been found in cuttings and cores, but formation tests carried out at frequent intervals have yielded no flow of oil.

In order to test the Corallian, from which series an outcropping oil sand had been found, a test well was drilled in a near-by anticline at Poxwell in Dorset. The Poxwell well started in the Portland beds and entered the Corallian at 995 ft. The sands at the horizon of the out-

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* D'Arcy Exploration Company, Ltd., London, England.

† *Trans.* A.I.M.E. (1937) **123**, 579.

cropping oil sand were well developed but showed no signs of petroleum and on test produced only water. Drilling was suspended at 1666 ft., in clays of the fuller's earth.

NOTTINGHAMSHIRE, LINCOLNSHIRE AND YORKSHIRE

Geophysical investigations have been continued in the licensed areas of east England in the attempt to solve the structural conditions of the Carboniferous underlying the unconformable blanket of Permian and younger sediments. Gravimeter, magnetic, torsion balance and pendulum traverses have been carried out and these have outlined certain areas of structural interest. These areas are now being detailed by seismic methods.

Northeastern Yorkshire.—A well to test the magnesian limestone of Permian age, from which limestone production of oil has been obtained at Volkenroda in north Germany, was started near Whitby on the Eskdale pericline, which is closed by rocks of Liassic age.

The Eskdale well entered the Trias at a depth of 1335 ft., and at a depth of 2486 ft. is still drilling in that formation.

SCOTLAND

A well to test the oil-shale group of the lower Carboniferous has been located on the Cousland dome about 15 miles southeast of Edinburgh. It was from a sand of this group that some 1700 gal. of oil was produced at D'Arcy in 1921, from a well drilled by Messrs. S. Pearson & Co. The Cousland test well entered the oil-shale group, the uppermost member of the calciferous sandstone series of the Lower Carboniferous, at a depth of 245 ft. To the present depth of 1303 ft., many cores of oil-impregnated sandstone have been recovered, but as yet formation tests have yielded no flow of oil, though at approximately 1200 ft. gas with only a small production was encountered.

MIDLANDS

Attention has been directed to the Lower Carboniferous limestone as a possible source of oil; it was from this limestone that some 2800 tons of oil have to date been produced at Hardstoft, a structure drilled east of the Pennines in 1918–1921 by Messrs. S. Pearson & Co. Geological field work has confirmed the existence of large structures closed in millstone grit on the western flank of the Pennine Range. One of these, Gun Hill, has been selected for a test of the limestones of the Lower Carboniferous.

Petroleum and Gas in Iran during 1937

FIELDS

Gach-Saran.—The most important development of 1937 has been the successful completion of initial exploratory wells in the Gach Saran (formerly known as Gach-i-Qaraghuli) field, about 125 miles southeast of Haft Kel. Two of these wells are rated at 33,000 bbl. per day at flowing pressures exceeding 800 lb. Drilling is proceeding with the object of delimiting the structure. Exploratory drilling is also being undertaken in several areas within the company's concession.

In the producing fields the policy of controlled production has been maintained as in the past, and drilling has been limited to that required for maintenance of production and general control of the fields. Acid treatment to increase production when desired has continued to be successful in most cases.

TABLE 1.—*Crude Production in Iran*

Year	Masjid-i-Sulaiman[a]		Haft Kel		Total	
	Tons	Barrels[b]	Tons	Barrels[b]	Tons	Barrels[b]
1936	3,641,247	27,820,000	4,473,849	34,200,000	8,115,096	62,020,000
1937[c]	4,375,112	33,110,000	5,693,849	43,480,000	10,068,961	76,590,000

[a] Net production; i.e., excluding surplus products re-injected to reservoir.
[b] To nearest 10,000.
[c] Correct to November, with an added estimated figure for December.

Masjid-i-Sulaiman.—There have been no new developments in this field. The policy of returning, as and when necessary, surplus products to the reservoir has been maintained.

Haft Kel.—Drilling to explore deeper formations has been undertaken, but has not progressed far enough for conclusive results to be drawn. Gasoline retention in the crude by means of multistage pressure stabilization has been continued as in past years. Separation pressures are as follows: well-head separators, 500 lb.; central battery, 190, 85, 40, 20 and 10 lb. per sq. in., respectively. The stabilized crude is delivered to pipe line at atmospheric pressure, or ex the 10-lb. stage, in accordance with refinery requirements.

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Total Production.—The production from these fields combined has increased by 2 million tons to slightly over 10 million tons for the full year. Table 1 gives a comparison of crude productions for 1936 and 1937.

Naft-i-Shah.—Production from this field has continued to supply market requirements in northwest Iran. The policy of returning surplus products to this reservoir has been adopted.

AERIAL SURVEY

During the year approximately 3500 sq. miles has been aerially surveyed for geological purposes.

Oil and Gas Production in Iraq during 1937

By Ben B. Cox,* Member A.I.M.E.

The Iraq Petroleum Company, Ltd. continued its systematic exploration and exploitation of the Kirkuk field on a unitized basis. Pressures, gas-oil ratios, oil-water level and oil-gas level remained satisfactory. All wells were produced by flowing and more than two-thirds of the crude was stabilized. The only exports from Iraq during 1937 were from the Kirkuk field.

Mosul Oilfields, Ltd., through its operating subsidiary, the British Oil Development Company, Ltd., inaugurated an exploratory program to find lighter oil than the heavy, black, sulphurous reserve proved in the Qaiyarah-Najmah-Jawan-Qasab field. Deeper drilling in this field found a small reserve of 17° to 19° A.P.I. black sulphurous oil in the Pilsner (Upper Cretaceous). Ten structures outside the proved field were tested or were under test at the end of the year. In spite of this intensive program no reserve of lighter oil was discovered. The reserve at Qaiyarah-Najmah-Jawan-Qasab averages 16° A.P.I. with 6+ per cent sulphur from the "continuous limestone" (Lower Miocene, Oligocene, Middle Eocene) and from the Pilsner (Upper Cretaceous).

The Khanaqin Oil Company, Ltd., a subsidiary of the Anglo-Iranian Oil Company, Ltd., conducted the normal exploitation of its Naft Khaneh oil field and supplied the local Iraq market requirements.

Slightly more than 31,600,000 bbl. of crude was produced in Iraq during 1937. The following table gives the total crude produced by the I.P.C. for export during the last four years.

Year	42-gallon Barrels[a]	Increase over Preceding Year
1934	7,096,669	
1935	27,014,904	19,918,235
1936	29,521,053	2,506,149
1937	31,171,476	1,650,423

[a] Converted at an average of 7.6 bbl. per ton.

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* Geologist, Socony-Vacuum Oil Co., Inc., New York, N. Y.

Petroleum Development in Mexico during 1937

By V. R. Garfias,* Member A.I.M.E., and A. C. Fernandez*

(New York Meeting, February, 1938)

Despite artificial curtailment in all the fields of Mexico during 1937, owing to strikes and other disturbances, the production of crude petroleum aggregated approximately 46,738,000 bbl., showing a substantial increase of about 5,571,000 bbl. over the preceding year. Most of this increase occurred in the Poza Rica area, where, although only two wells were completed during the year, production increased from 14,162,000 bbl. in 1936 to 18,634,000 in 1937. While production in the South fields (Golden Lane) remained practically stationary, the output in the heavy-oil district of the Northern fields showed an increase of 1,930,000 bbl., because production had been considerably curtailed during 1936. Production in the Isthmus of Tehuantepec decreased about 596,000 bbl., owing to labor disturbances.

Crude run to stills in local refineries increased from 34,000,000 bbl. in 1936 to 36,650,000 in 1937. Exports of crude and refined products were approximately 22,700,000 bbl., or 500,000 bbl. less than in 1936. Domestic consumption, excluding ships bunkers, reached a total of 20,000,000 bbl., which shows a small increase of 200,000 bbl. over the previous year. Domestic demand for gasoline is estimated at 3,400,000 bbl. for the year, which represents an increase of 500,000 bbl. over 1936.

In all, 60 wells were completed in Mexico during 1937, as compared to 70 in 1936 and 74 in 1935. In proven areas 52 completions resulted in 25 producers and 27 failures. In the Northeastern area near the United States border, five gas wells were drilled, all of which were producers; one of them, in Camargo, came in with a daily production of 20,000,000 cu. ft. of gas. One well, resulting in a failure, was drilled in Las Uvas, Coahuila, and three wells were completed in Quebrache, to the southeast of the heavy-oil district, resulting in two small producers and one failure. Two more wells drilled in San Sebastián, east of the Golden Lane, were failures.

Fields

Northern Fields (Heavy-oil District).—A total of 11 producers and 22 failures was completed in the proven areas of the Northern fields, as compared to 16 producers and 25 failures in 1936. In the Altamira

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* Cities Service Co., New York, N. Y.

district, 11 wells were drilled, resulting in two producers and nine failures. Production of the Northern fields totaled 9,828,000 bbl., an increase of 24 per cent over the previous year, not to be attributed to a normal increase in the production, as during 1936 the output of this field was greatly curtailed by shutdowns due to strikes, etc.

South Fields (*Golden Lane*).—Only one well was drilled in the producing area of the Golden Lane proper, resulting in a failure, and three small producers and two failures were completed to the north of this line in Rancho Abajo and San Miguel Tres Aguas. Production maintained an even trend, showing a small decrease of 208,000 bbl. from the preceding year.

Poza Rica.—Only two wells, both large producers, were completed in this area during the year. One well was drilled on lot 30, in the southern limits of the proven area, and the other, on lot 70, extended the field 1¼ miles to the southeast. At the end of 1937 the proven area was estimated at 8¼ square miles. Production showed an increase of 31.5 per cent over 1936.

Isthmus of Tehuantepec.—The rate of development continued the same as during 1936, with 11 completions, of which 9 were producers. Shutdowns due to labor difficulties and strikes caused a decline in production of 596,000 bbl. from the previous year.

Northeastern Mexico.—In all, five producers and three failures were completed in this area. The producers were all gas wells, one in Camargo, with a production of 20,000,000 cu. ft. per day; another in Nuevo Laredo, about 3 miles south of the United States border, with 13,000,000 cu. ft. of gas per day, and the other three in Mier, with a combined daily production of 8,000,000 cu. ft. of gas. Two dry holes were completed in Zacate, Nuevo Leon, and one in Las Uvas, Coahuila.

TABLE 1.—*Production of Oil In Mexico*

U. S. BARRELS

Fields	1936	1937	Total since Discovery to End 1937	November 1937	Number of Producing Wells Nov. 1937
Northern (11° to 14° A.P.I.)	7,898,000	9,828,000	733,972,000	752,000	556
Southern (Golden Lane, 20° to 24° A.P.I.)	8,409,000	8,201,000	1,013,112,000	628,000	215
South fields, miscellaneous	121,000	93,000	5,019,000	7,100	14
Poza Rica (33° to 34° A.P.I.)	14,162,000	18,634,000	46,969,000	1,973,000	17
Isthmus of Tehuantepec (32.5° A.P.I.)	10,576,000	9,980,000	90,642,000	838,000	200
	41,166,000	46,736,000	1,889,714,000		

Prices and Taxes

The price of heavy crude spot cargoes f.o.b. Tampico increased from $1.11 per barrel at the end of 1936 to $1.35 by the middle of March 1937, but in September the price dropped to 96¢, remaining steady at this level until the end of the year. The average price in 1936 was 95¢ per barrel, $1.00 in 1935, 80¢ in 1934, 60¢ in 1933, 44¢ in 1932, 55¢ in 1931, 60¢ in 1930, 65¢ in 1929 and $1.05 in 1928.

Southern crude not controlled by local refineries sold at an average price of 55 cents per barrel at the well, compared to 45 cents in 1936. No sales of Poza Rica crude were made during 1937.

Table 2.—*Mexican Oil Taxes*

U. S. Cash per Barrel

	December 1936	December 1937
Heavy crude	$0.117	$0.127
Light crude	0.188	0.204
Fuel oil	0.168	0.184
Refined gasoline	0.117	0.120
Crude gasoline	0.252	0.257
Refined kerosene	0.074	0.093
Crude kerosene	0.152	0.190
Lubricants	0.148	0.148

Outlook for 1938

It is expected that drilling activity and production will decline in the Northern and South fields during 1938. Production in Poza Rica will largely depend on the attitude of the Mexican Government regarding the issuing of drilling permits and on the result of the drilling campaign of the Petronac—the Government-owned company. The total output of the Mexican fields in 1938 may well reach over 50,000,000 bbl., the increase coming largely from Poza Rica.

Oil and Gas Production in the Netherlands Indies, Sarawak and Brunei*

Line Number		Age, Years to End of 1937	Total Oil Production, Bbl.			Daily Average during Dec. 1937	Average Oil Production, Bbl. per Well Daily during Dec. 1937	Total Gas Production, Millions Cu. Ft.	
			To End of 1937	During 1936	During 1937			During 1936	During 1937
1	Sarawak + Brunei	28	78,542,825	4,861,000	5,733,000	16,380	36	3,012	3,423
2	B. Papan + Tarakan	42	343,586,660	12,546,000	12,309,000	33,774	47	9,984	10,903
3	Ceram	41	5,528,705	349,000	497,000	1,677	39	18	13
4	Tjepoe	50	86,126,191	3,774,955	7,198,446	19,452	44	2,808	4,526
5	Pladjoe	41	233,829,304	26,285,460	28,118,053	33,000	74	12,482	12,526
6	P. Brandan	52	119,541,895	5,688,000	6,777,000	20,516	177	6,134	7,617
	Total		867,155,580	53,504,415	60,632,499	124,799	56	34,438	39,008

1 cu. m. = 35.31 cu. ft.

Line Number	Number of Oil and/or Gas Wells							Depth, Average in Feet		Oil Production Methods at End of 1937		
	Completed to End of 1937	During 1937		At End of 1937				Bottoms of Productive Wells	To Top of Productive Zone	Number of Wells		
		Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Gas Only	Total Producing			Flowing	Pumping	Gas-air Lift
1	566	25	1	15	452	2	469	340–5,280	130–5,242	13	403	36
2	1,361y	47	12		715	2	717	230–2,620	210–2,600	29	670	16
3	80	3	1		43	2	45	260–1,020	240–1,000		43	
4	2,695y	191	6	79	1,267	2	1,378	160–2,950	130–2,880	36	401	3
5			13	30				290–5,400	160–5,200	97	104	244
6	747	20	5	17	116	.	133	300–4,140	260–4,100	48	30	38
	6,449	286	38	141	2,593	8	2,742			223	1,651	337

Line Number	Producing Rock					Number of Dry and/or Near-dry Holes to End of 1937	Deepest Zone Tested to End of 1937	
	Name	Age^{f}	Character^{g}	Porosity,^{h} Per Cent	Structures^{i}		Name	Depth of Hole, Ft.
1	Seria and Miri formations	Mio	SsH	18	Af	81	Miri deep shale	6,180
2	Balik Papan-Poeloe Balang and Tarakan formation	Pli + Mio	SsH, S	10–30	Af	216y	Poeloe Balang	5,250
3	Boela formation + Triassic	Pli + Tri	SsH	y	Af	41	Triassic	2,400
4	Mergelklei—Globigerinae—Orbitoid zones	Pli + Mio	S, SH, LS	15–35	Af	317y	Basis mergelzone	5,900
5	Palembang and Telissa zones	Pli + Mio + Paleogene	S, SH, SS	13–28	Af	367y	Under Telissa	7,550
6	Seuroela-Keutapang-Grensklei zones	Pli + Mio	S, SH, SS	y	Af	249y	Grensklei	6,680

y Footnotes to column heads and explanation of symbols are given on page 313.

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* Received through the courtesy of N. V. de Bataafsche Petroleum Maatschappij, The Hague, The Netherlands. Manuscript received at the office of the Institute March 2, 1938.

Petroleum Developments in Peru during 1937

By Oliver B. Hopkins,* Member A.I.M.E.

(New York Meeting, February, 1938)

Peru produced approximately 17,466,620 bbl., of oil during 1937, or slightly less than the record high of 17,593,700 bbl. established during 1936. As in 1936, the entire output of the country was derived from the La Brea-Parinas, Lobitos-Restin and Zorritos fields in the northwestern part of the country.

Outside of the proven areas, drilling was continued by the Peruvian Government in the northern province of Tumbes on the reserved zone at Zorritos. Drilling was carried out on three locations, two of which are understood to have been abandoned during the year. In southern Peru, further attention was given by Government engineers to the Pusi and Saman districts and plans are being worked out for the commencement of drilling operations in the near future in the vicinity of Pirin. Activities in the montaña region in eastern Peru were continued by the Compañia Petrolera El Ganso Azul. This company acquired the interest of the Selden Breck Co., and holds some 90,000 acres along the Pachitea River a few miles above its confluence with the Ucayali. During the year, the preparation of a landing place, the cutting of a 12-km. (7½-mile) road from the river to the drill site, and the construction of a camp were undertaken. Equipment for drilling on this company's concessions has already arrived in South America.

La Brea-Parinas Estate.—Production of crude oil on the La Brea-Parinas Estate of the International Petroleum Company Limited amounted to 14,722,754 bbl. during 1937, a decrease of 403,736 bbl. from the all-time high reached during 1936. The total production from 1890 to Dec. 31, 1937, was 178,390,767 bbl. During 1937, a total of 141,653 ft. was drilled, 129,516 ft. in new wells and 12,137 in deepening existing wells. In all, 57 wells were completed, 47 of which produced oil, 2 were gas wells and 8 dry holes.

Twenty-nine wells were cleaned out or deepened during the year. The average depth of new wells completed during 1937 was 2367 ft. compared with 1984 ft. for the new wells completed during 1936. There was an increased use of rotary tools during the year and this method is now used to a greater extent than the cable-tool method, which formerly predominated. Of the 57 wells completed during the year, 31 were

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* Chief Geologist, Imperial Oil, Limited, Toronto, Ont., Canada.

drilled by rotary, 12 by standard and 14 by star rigs. The average depth of rotary wells was 3016 ft. compared with 1960 ft. for standard tools and 1278 ft. for star rigs.

Drilling operations during the year were mainly routine, the locations being situated in or about proven territory. Two locations, drilled in wildcat territory in the northern part of the estate, were not commercially productive. The cleaning out and deepening of older wells has continued to yield beneficial results.

Study and experimental work is being undertaken with the object of determining the feasibility of water-flooding in certain of the older sections of the field, but it will probably be some time before the results of these investigations are known.

The seismograph survey commenced during 1936 was completed during 1937 and in addition gravity-meter and magnetometer surveys were completed over a very extensive area on the estate.

TABLE 1.—*Oil and Gas Production in Peru*

Line Number	Field, *Department*	Age, Years to End of 1937	Area Proved, Acres			
			Oil	Oil and Gas[a]	Gas	Total
1	La Brea-Parinas, *Piura*	48	*y*	*y*	*y*	*y*
2	Lobitos and Restin, *Piura*	33	*y*	*y*	*y*	*y*
3	Zorritos, *Tumbes*	54	*y*	*y*	*y*	*y*
4	Pirin (Huacane), *Puno*	*x*	*y*	*y*	*y*	*y*
	Total					

[a] Footnotes to column heads and explanation of symbols are given on page 313.

Line Number	Total Oil Production, Bbl.				Total Gas Production, Millions Cu. Ft.				Number of Oil and/or Gas Wells							
										During 1937		At End of 1937				
	To End of 1937	During 1936	During 1937	Daily Average during Nov. 1937	To End of 1937	During 1936	During 1937	Maximum Daily during 1937	Completed to End of 1937	Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Oil and Gas[b]	Producing Gas Only	Total Producing
1	178,390,767	15,126,490	14,722,754	39,389	*x*	*x*	*x*	*x*	2,973	57	8	72[1]	*y*	1,812	17	1,901[2]
2	41,316,242	2,418,198	2,693,866	7,380	*x*	*x*	*x*	*x*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*
3	3,140,223	49,012	50,000	137	*x*	*x*	*x*	*x*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*
4	285,936	0	0	0	*x*	0	0	0	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*
	223,133,168	17,593,700	17,466,620													

[1] Includes all injection wells.
[2] Includes water wells used for injection purposes, but not other water wells.

Lobitos Property.—This property, north of the La Brea-Parinas Estate, produced 2,693,866 bbl. during 1937, an increase of 275,668 bbl. over 1936. Total production to the end of 1937 amounted to 41,316,242 bbl. The most outstanding development on this property during the year was the completion of several good wells in the El Alto or northern section of the field, where four of the wells completed had initials of approximately 500 bbl. per day. Much work was also done in deepening old wells, with a very gratifying measure of success.

Zorritos Property.—The Zorritos property, operated by Piaggio and Co., is estimated to have produced approximately 50,000 bbl. during 1937.

TABLE 1.—(*Continued*)

Line Number	Depth, Average in Feet		Oil Production Methods at End of 1937						Pressure, Lb. per Sq. In.[d]			Character of Oil, Approx. Average during 1937				
			Number of Wells							Average at End of		Gravity A.P.I. at 60° F.				
	Bottoms of Productive Wells	To Top of Productive Zone	Flowing	Pumping	Gas-lift	Air-lift	Miscellaneous	Injection into Reservoir[c]	Initial	1936	1937	Maximum	Minimum	Weighted Average	Sulphur, Per Cent	Base[e]
1	y	y	74	1,718	20		43[3]	46[4]	y	y	y	H.C.T. 39.2 L.C.T. 34.6	H.C.T. 38.8 L.C.T. 33.6	H.C.T. 39.0 L.C.T. 34.0	y	M
2	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y
3	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y
4	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y

[3] Does not include water wells, but includes gas wells and wells shut down for various reasons.
[4] Includes water wells used for injection purposes.

Line Number	Character of Gas, Approx. Average during 1937		Producing Rock						Number of Dry and/or Near-Dry Holes to End of 1937	Deepest Zone Tested to End of 1937	
	B.t.u. per Cu. Ft.	Gal. Gasoline per M Cu. Ft.	Name	Age[f]	Character[g]	Porosity[h]	Net Thickness, Average in Feet	Structure[i]		Name	Depth of Hole, Ft.
1	y	y	Verdun, Lomitos, Parinas Negritos, Salina	Eocene	S	y	x	AF	y	Eocene	
2	y	y	Terebratula, Lower Caverno	Eocene	S	y	x	AF	y	Probably Cretaceous	y
3	y	y	Zorritos	Miocene	S	y	x	MF?	y	y	2,900?
4	y	y	y	y	y	y	x	y	y	y	y

Oil and Gas Production in Poland during 1937

By Charles Bohdanowicz*

(New York Meeting, February, 1938)

Production of crude in 1937 decreased (Tables 1 and 5) by about 2 per cent, while gas production for that period increased by about 6 per cent after a slight decrease in 1936 (0.4 per cent).[1] As in preceding years, drilling operations were confined principally to extensions of old oil fields in the Jaslo district (fields 1 and 7) and to some extent to such extensions in the Stanislawów district (field 27). Deepening of old wells to horizons reached more recently by new wells gave on the average better results per well than those attained by new wells (Table 3).

Reserves of proved lands have increased some by new oil fields discovered, Targowiska (field 8) and Czarna (field 19) both of which, however, have only small production. The Daszawa gas field (field 25) has not been extended, but two new gas fields were located instead—Opary, distant 25 km. (15½ miles) northwest of Daszawa, Balicze at 12 km. (7¼ miles) southeast of Daszawa, and Kalusz (TESP Company exploiting potassium salts) in the vicinity of the town of that name (field 33). Drilling upon the gas area near Tarnów and Dębica, while gas-bearing sandstone had been found at depths of from 300 to 512 meters (984 to 1680 ft.) (Zdziary No. 2) and at 220 m. (722 ft.) [pressure 11 atmospheres, flow 24 cu. m. per min. (847 cu. ft.)] (Przyborów No. 1), has not as yet ascertained horizons qualified for permanent exploitation. The exploring well near Kosów remained for the last seven months at the depth of 1420 m. because of the collapse of rotary drilling pipe. Below the 300-m. level no gas sands have been encountered at this well.

Gas Reserves

In connection with the broad plan of developing industrially the sector of Poland lying between the Vistula and the San Rivers, and extending farther north as far as the city of Radom, there arose the necessity of a more accurate calculation of gas reserves for the fields of

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[1] Figures for 1936 shown in the *Trans.* A.I.M.E. (1937) **123**, 611, have been corrected (Tables 1 and 6) on the basis of official data. Expectations for a large gas production in 1936 have not materialized as new completions influenced the volume of gas production only in 1937. The author is indebted to Mr. A. Nieniewski, of Krosno, for some data concerning the Jaslo district.

Roztoki (field 5) and Daszawa (field 25). The field of Roztoki and others of that group are situated upon the uplift of Potok.

For calculating the gas reserves of the country, the Polish Geological Survey has adopted classification of tracts by three principal groups:

I. Tracts in exploitation, the area of which may be defined with sufficient accuracy (proved).

II. Tracts upon which gas horizons have been ascertained, but are not yet exploited, and the confines of which could not, as yet, be defined (probable).

TABLE 1.—*Oil and Gas Production in Poland*

Line Number	Field, *Province*	Age, Years to End of 1937	Area Proved, Acres			
			Oil	Oil and Gas[a]	Gas	Total
1	Lipinki, Libusza, Kryg, Kobylanka, Dominikowice, Wojtowa, *Gorlice*	72	1,075			1,075
2	Korczyna, Biecz, *Gorlice*	40	65			65
3	Sekowa, Ropica, Mecina, Siarg, Szymbark, *Gorlice*	65	100			100
4	Harklowa, *Jaslo*	67	130			130
5	Roztoki-Sadkowa, Dobrucowa, Bialk.-Brzezowka, Sobniow, *Jaslo*	28	889	445	500	1,850
6	Mecinka, Jaszczew, *Jaslo-Krosno*	28				
7	Potok-Toroszowka, *Krosno*	46				
8	Krosno Kroscienko-Targowiska, *Krosno*	49				
9	Bobrka-Rogi-Rowne-Wietrzno, *Krosno*	79	225			225
10	Iwonicz-Klimkowka, *Krosno*	47	?			?
11	Ropianka, *Krosno*	69	30			30
12	Strachocina-Gorki, *Brzozow-Sanok*	9			494(?)	494(?)
13	Zmiennica-Turzepole, *Brzozow*	41	67			67
14	Starawieś-Brzozow-Humniska-Grabownica, *Brzozow-Sanok*	41	321			321
15	Weglowka, *Krosno*	50	148			148
16	Lubatowka-Wulka, *Krosno-Sanok*	49	275			275
17	Mokre-Tarnawa Sol.-Zagorz, *Sanok*	25	50			50
18	Total Jaslo district		3,129	766	869(1,000?)	4,764(5,150?)
19	Rajskie-Polana-Lipie, Czarna, *Lesko*	51	100			100
20	Lodyne-Wankowa-Ropienka-Paszowa-Stankowa, *Lesko*	51	568			568
21	Strzelbice, *Sambor*	56	62			62
22	Opaka, *Drohobycz*	41	25			25
23	Boryslaw (deep "skiba"), *Drohobycz*	43				3,700
24	Schodnica-Urycz,	65	1,110			1,110
25	Daszawa-Olekice Nowe-Opary, *Drohobycz*	16			1,500	
26	Total Drohobycz district				1,500	6,765
27	Rypne-Duba-Perehinsko, *Dolina*	50	1,500			1,500
28	Bitkow, *Nadworna*	38	1,080		100	1,180
29	Pasieczna, *Nadworna*	57	400		150	550
30	Majdan-Rosulna, *Kalusz*	48	220			220
31	Sloboda Rungurska, *Kolomyja*	62	120			120
32	Kosmacz, *Kolomyja*	37	40			40
33	Kalusz, *Kalusz*	2	?			?
34	Total Stanislawow district					
35	Total Poland with other fields					

[a] Footnotes to column heads and explanation of symbols are given on page 313.

III. Tracts qualified for explorative drilling for gas.

Upon the Potok fold may be delimited the following: (1) The principal uplift exhausted already to a considerable extent. Reserve of group I in two horizons still approximates 200,000,000 cu. m.; (2) the sector of the fold Sądkowa—Roztoki—Gliniacz—Sobniów. Reserve of group I: From a strip 3.5 km. (2.2 miles) (Sądkowa-Roztoki) calculated at 1,700,000,000 cu. m. on the basis of the lowest working pressure practicable, one atmosphere, while with the working pressure bottom limit at 25 atmospheres the computable reserve would amount to only 1,150,000,000 cu. m. Reserve of Group II: Upon a sector of the field 5.4 km. long, if gas

TABLE 1.—(*Continued*)

Line Number	Total Oil Production, Bbl.				Total Gas Production, Millions Cu. Ft.				Number of Oil and/or Gas Wells
	To End of 1937	During 1936	During 1937	Daily Average during Nov. 1937	To End of 1937	During 1936	During 1937	Maximum Daily during 1937	Completed to End of 1937
1	4,619,994	233,100	(+19 %)277,970	862	x	50	61.5	0.29	914(94?)
2	376,610	29,674	28,210	72	x	63	65	0.18	53
3	741,995	17,109	(+21 %)20,720	70	x	3.5	3.3	x	174
4	1,693,272	60,902	(−14 %)52,430	140	x	36	39	0.105	273
5	212,144	40,404	35,580	90	52,884	3,136	(+11 %)3,492(?)	12.7	36
6	215,688	38,850	27,580	61		395	406	1.8	19
7	5,438,028	125,302	(−2.1 %)98,210	67	x	143	140	0.7	255
8	1,947,892	31,872	30,100	87	x	8.7	10.7	0.4	109
9	5,482,836	54,751	(−6 %)51,450	147	x	159	123	0.3	250
10	x	17,020	13,346	38	x	30	22	0.00	55
11	x	2,146	1,750	5	x	20	.26	0.07	37
12					942	128	162	?	3
13	678,820	17,020	15,260	44	x	35	32	0.1	57
14		83,768	80,990	221	x	321	262	0.927	111
15	2,000,585	27,158	26,320	77	x	24	27	0.088	225
16		14,490	15,813	43	x	21	21	0.06	85
17		10,000	12,650	40					29
18	25,318,090	755,230	(+4.4 %)788,379	(+3.0 %)2,470	58,186	4,640	(+5.5 %)4,892		2,700
19		14,933	19,810			4	3.5		71
20	5,164,000	173,382	161,630			53	45		445
21	604,478	21,460	18,648	49		10	9		73
22	135,749	2,960	2,659						15
23	179,675,774	1,899,240	1,820,000	(−3.7 %)5,200	192,262	4,555	(−4 %)4,367	12.6	1,295
24	19,904,903	355,886	338,030			207	243		806
25						5,203	(+10 %)5,731	15	24
26	208,159,676	2,452,310	(−3.4%)2,368,100	(−6.3 %)6,650	240,000	10,698	(−2.8 %)10,398	35	2,737
27	2,272,520	128,760	101,290	2,750		432	523		233
28	6,223,074	174,846	149,800	(−11.3)440		1,376	1,327	3.6	184
29		42,376	30,000	77			95	0.3	195
30		20,438	19,180	51					103
31		11,944	10,640						300
32	214,568	3,922	3,668						10
33					445	95	350	3	3
34		366,870	(−11.3 %)325,290		35,295	2,032	(+12 %)2,295	6.3	1,050
35	244,448,984	3,574,410	(−2.4 %)3,481,769		333,480	17,061	(+6 %)18,144		6,487

conditions prove the same as on the Sądkowa-Roztoki sector, the reserve might approximate 2,600,000,000 cu. m. Thus the proved and probable reserves of this structure may amount to 4,300,000,000 cu. m. of gas (151,833,000,000 cu. ft.).

Upon the Strachocina-Górki fold (field 12) only a group II reserve may be estimated, which, with the working pressure bottom limit at one atmosphere may be computed at 1,100,000,000 cu. meters.

For the Daszawa area (Daszawa, Chodowice, Oleksice Nowe) which has been worked for 13 years (21 wells) over a surface of 5 sq. km. (1235½ acres) the gas reserve may be computed at 4,000,000,000 cu. m. The

TABLE 1.—(*Continued*)

	Number of Oil and/or Gas Wells							Depth, Average in Feet		Oil Production Methods at End of 1937					Pressure, Atm. or Kg. per Sq. Cm.		
	During 1937		At End of 1937							Number of Wells						Average at End of	
Line Number	Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Oil and Gas[6]	Producing Gas Only	Total Producing	Bottoms of Productive Wells	To Top of Productive Zone	Flowing	Pumping	Gas-lift	Air-lift	Swabbing	Initial	1936	1937
1	85(?)	13	29	549		1	550	1,500(2,850)			494			55		2–25	2–25
2	4	1	1	40			40	480–1,440			40						
3	8(?)		24	94		2	96	720			77			17			
4	2		4	135		1	137		720		133			3			
5	3	6	2	9		22	31	2,400–4,160				5		4	115		99
6	1		1	8		6	14		2,700			4		4	110	38	?
7	7	3	7	85		4	89	416–1,120	2,100 500	1	80			4	35	15	
8	1	1	2	43			43	900–2,000	1,600		43					5–10	?
9	0	31	7	88		3	91	480–3,200			50			26	60	?	?
10	4		3	17		3	20	360–1,120	600		17						
11	0		6	18			18	380–1,120			13			5			
12	0		1			2	2	2,590 to 4,050							80–93		?
13	1	1	1	37			37	1,480			33			4			
14		4	6	58		1	58	2,300			29	1	4	24	50	5	5
15			5	83			83	1,050			83						
16	2		2	16			16	1,480			16						
17	3	6	2	29			29	1,800			26			3			
18	121	66	120	1,339		45	(1,384) 1,401(?)			17	1,181			158			
19	10	8		16			16	1,310 350			16						
20	14		26	362			362	1,150 to 1,900			362						
21	0		10	39			39	660			39						
22	0		2	5			5	1,970			5						
23	9		260	586		125	711	4,270 to 5,700			76			510			
24	27			539			539	1,480			539						
25	5		3			21	21	2,300 1,280							Darzawa Opary-36	63–47	45–39 36
26	74			1,562		150	1,712(?)				1,047			515			
27	15		6		134		134	2,625			86			38			
28	10		76		98	10	108	3,610		8	5			85			
29	3		10		40		40	660 to 4,700			12			28			
30	2		10	71			71	1,150			50			17			
31	0			51			51	985			51						
32	0			10			10	1,920			10						
33	2					3	3	2,400							40(?)		40(?
34	32						417(?)			10	214			168			
35	238(?)						3,530										

fields of Opary and Balicze may, so far, be qualified as probable and possible gas areas, while in the vicinity of the city of Kalusz exploitation of gas has just begun.

A general defect of the gas policy in Daszawa is the absence of any concerted exploring and exploitation drilling program, although possession of that area is shared by only two large operators (Gazolina and Polmin). The field of Roztoki, 3 km. (1.8 miles) long, is owned by one operator (Polmin). In Daszawa, of a total number of 21 wells, 7 are either flooded or are in a condition that makes measurement of pressure impossible.

TABLE 1.—(*Continued*)

	Character of Oil, Approx. Average during 1937					Character of Gas, Approx. Average during 1937		Producing Rock					
	Gravity A.P.I. at 60° F.												
Line Number	Maximum	Minimum	Weighted Average	Paraffin Per Cent	Base[e]	B.t.u. per Cu. Ft.	Gal. Gasoline, Grams per C. C.	Name	Age[f]	Character[g]	Porosity[h]	Net Thickness, Average in Feet	Structure[i]
1	32	38	34	3.0–7.4	P	1,124		Ciezkowice I, II a. Cre	Eoc, Cre	S	18.7–21.3	80	AM
2	38	43	39	0.3–1.1	A	1,124		Ciezkowice I, II	Eoc	S		120	diapir
3	29	40	35	0.4	A			Magura facies	Cre	S		40	A
4	21	27	27	0.8	A			Krosno beds	Olig	S		150	overthr.
5	40	42	40	0.4	A	1,011	10–45	Ciezkowice II, III	Eoc, Cre	S	12.2	245	diap.
6	42		42	4.0	P		25–50	Ciezkowice II, III	Eoc, Cre	S		198	diap.
7	39	51	42	0.4	A	1,124	150	Ciezkowice II, III	Eoc, Cre	S		80	diap.
8	29	34	32	0.7–8.0	M		150	Ciezkowice I, II	Eoc	S		190	diap.
9	32	38	34	0.5–6.2	AP		225	Ciezkowice I–III, IV	Eoc, Cre	S		160	A
10			35		A			Krosno beds	Olig	S		132	A
11	29	31	31	0.4	A			Magura facies	Cre	S		60	A
12						1,124	13	Czarnorzecki	Cre	S			A
13			33	6.7	P			Ciezkowice I	Eoc	S		100	A
14	37	47		0.2–5.9	A,P	1,067	150	Ciezkowice I, II, III	Eoc, Cre	S	19.6 18.4 20.5	200	diap.
15	27	30	29	0.4	A			Czarnorzecki	Cre	S		100	AM
16			29	0.3	A		150	Ciezkowice I–III	Eoc, Cre	S		100	A
17	35	45	44	0.3	A			Krosno beds (lower)	Olig	S		?	Af
18													
19	38	45	42	5.1–0.1	P,A			Krosno beds (lower)	Olig	S		?	Af
20	30	39	34	0.5–5.9	P			Krosno beds (lower) and Menilite series (upper)	Olig	S		40–50	diap.
21	21	33	32	6.2	P			Jamna beds	Cre	S		45	A
22	42	44	43	6.1	P			Eocene beds lower	Eoc	S		50	A
23	31	36	33	6.0–9.4	P	1,461	234	Boryslaw sandstone (IV Nor., V-Eoc, I–II olig)	Olig (Eoc, Cre)	S	10.0 15.0 17.4	IV = 30–120	AF
24	29	39	36	0.3–5.9	AP			Jamna beds	Cre	S		150	A
25								Gas beds (Tortonian)	Mio	S	25.0	100	A
26													
27	33	39	36	4.6–8.0	P			Kliwa beds	Olig	S		60	AF
28	34	48	44	1.1–8.4	P			Kliwa beds	Olig	S		15–30	AF
29	38	56	45	0.2–4.9	AP	1,067		Kliwa beds a. platy beds	Olig, Cre	S		15–30	AF
30	29	37	34	0.8–1.1	A			Eocene beds	Eoc	S		60–80	A
31	35	37	37	5.2–5.9	P			Jamna beds	Cre	S		80	Af
32	30	33	32	0.8–1.1	A			Inoceramus beds	Cre	SH		40	A
33								Gas beds (Tortonian)	Mio	S		?	?
34													

Limits of extent of the Roztoki field could not yet be defined, although the eleventh exploiting well is being drilled.

Beside the existing gas line, Roztoki-Tarnów (Mościce), there was laid in 1937 a gas line (12 and 10-in. respectively) from Roztoki to Sandomierz-Ostrowiec-Starachowice (280 km). In 1938 this line is to be extended to the city of Radom, and from that trunk-line branches are to be laid to Rzeszów and Rozwadów. The high-pressure main is to carry a working pressure of 35 atm. and it is planned to transport 500,000,000 cu. m. of gas annually (900 cu. m. per min.). That plan is based upon the hypothesis that upon the Roztoki field may be located 300 wells, each having a summary production of 20,000,000 cu. m. of gas,[2] in other words, that plan is based upon an elementary hypothesis of a 6,000,000,000-cu. m. gas reserve in that field. Neither the computation quoted in the preceding paragraphs nor the insufficient state of exploration of the Roztoki field justify such a hypothesis, nor is justified another hypothesis to the effect that the probable reserve of Daszawa-Opary runs up to 15,000,000,000 cu. m. of gas.[3]

TABLE 2.—*Drilling Statistics, Poland*
METERS[a]

Year	Jaslo	Outside Boryslaw	Boryslaw Fields	Stanislawów	Total
1937	69,088 (50 %)	32,605 (23.4 %)	11,900 (8.5 %)	25,242 (18.2 %)	138,835 (100 %)
1936	48,166 (45 %)	30,307 (28.0 %)	9,154 (8.5 %)	19,374 (18.5 %)	107,001 (100 %)
1935	37,682	23,166	10,638	12,530	84,016 (86,122)
1934	38,080	19,480	8,219	8,824	74,603 (77,933)
1933	32,382	19,418	7,582	7,519	66,901
1932	25,267	17,690	8,063	7,458	58,478
1931	28,666	20,749	14,444	10,653	74,512
1930	38,551	30,251	28,616	19,180	116,598

[a] One meter = 3.281 feet.

PRODUCTION OF OIL

Production of crude oil in Poland has declined since 1925; also, the average production per well (Table 3). So far, the rather weak explorative action has not led to any discovery of new fields of importance, nor has the increased number of meters drilled in 1936 and 1937, especially in the Jaslo and Stanislawów districts, been able to compensate for the drop of production at the principal fields of Boryslaw, Bitków and Rypne (Table 1). In order to keep production at the volume of 1936–1937, and even to increase it by 10 per cent in 1940, it would be necessary, according to the opinion of the Association of Polish Petroleum Engineers

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[2] S. Dażwański: *Przemysl Naftowy* (Sept. 10, 1937) **10**, 366.

[3] Dr. K. Tołwiński: In article of reference 2.

(Boryslaw), to intensify drilling of exploitation wells so as to bring up the meterage drilled to 150,000 in 1938, and to 225,000 in 1939.

Terrain accommodation for locating those new exploiting wells is adequate on all fields, but is least so in Boryslaw. In 1939 the number of new wells would need to approximate 380 (vs. 246 (?) in 1937). A certain increase in home consumption calls for providing for an adequate increase in production of crude oil in this country by at least 10 per cent in 1940,

TABLE 3.—*Number of Wells Completed*

Districts	1937		1936	
	New Wells	Old Wells Deepened	New Wells	Old Wells Deepened
Jaslo				
Producing	115	43	102	43
Nonproductive	13	11	22	7
Outside Boryslaw				
Producing	52	5	61	9
Nonproductive	10		7	1
Boryslaw				
Producing	8	8	15	4
Nonproductive	1	6	3	5
Stanislawów				
Producing	36	12	32	6
Nonproductive	11	2	8	3
Total				
Producing	211 (?)	68	210	62
Nonproductive	34	19	40	16
Average daily production per well, kg.	1200	1600	1800	1700

TABLE 4.—*Number of Producing Wells*

Year	Jaslo	Outside Boryslaw	Boryslaw Fields	Stanislawów	Total
1937	1,401	1,001	711	417	3,530
1936	1,291	1,002	669	396	3,358
1935	1,149	1,025	650	253	3,208 (other fields 203)
1934	1,195	1,046	632	248	3,121 (with other fields)
1933	1,117	1,009	603	245	2,974
1932	1,065	990	598	246	2,899
1931	1,027	963	574	250	2,814
1930	951	952	562	250	2,715

or up to 56,000 cars; which, in turn, would call for drilling in that year up to 480,000 m. or, approximately, 900 wells. Such a drilling program would entail drilling expenditures running in 1938 up to 44 million zlotys (approx. 5 million dollars) in 1938; to 70 million zlotys in 1939 and to 120 million zlotys in 1940, on the premises that drilling an exploiting well to a depth of 1200 m. (3,937 ft.) would cost 360,000 zlotys ($40,392), while the cost of drilling an exploring well to a depth of 2000 m. would amount to 1,800,000 zlotys.

TABLE 5.—*Total Oil Production, Poland*

IN CARS (10,000 KG., OR 10 TONS)[a]

Year	Jaslo	Outside Boryslaw	Boryslaw Fields	Stanislawów	Total
1937	11,589 (23 %)	7,830 (15.7 %)	26,000 (52 %)	4,647 (9.3 %)	50,066 (−2.0 %)
1936	10,789 (21 %)	7,901 (15.0 %)	27,132 (53.2 %)	5,241 (10.5 %)	51,068 (−0.8 %)
1935	9,908	9,429	28,598	3,541	51,476
1934	9,953	9,141	30,426	3,268	52,788
1933	9,645	9,588	32,514	3,320	55,067
1932	9,582	9,043	33,029	4,014	55,668
1931	9,765	9,491	39,070	4,702	63,028
1930	8,535 (13 %)	8,561 (13 %)	44,334 (67 %)	4,847 (7 %)	66,277

[a] One 10-ton car = 74 barrels.

TABLE 6.—*Total Gas Production, Poland*

THOUSANDS OF CUBIC METERS[a]

Year	Jaslo	Outside Boryslaw	Boryslaw Fields	Stanislawów	Total
1937	138,570 (27 %)	182,862 (35.5 %)	127,464 (24.8 %)	65,085 (12.2 %)	513,981 (+6 %)
1936	131,427 (27.2)	165,258 (34.2 %)	129,048 (26.7 %)	57,560 (12.0 %)	483,303 (−0.4 %)
1935	136,476	168,507	137,390	43,036	485,409
1934	121,200	149,722	154,516	43,300	468,738
1933	97,664	142,978	176,972	44,597	462,211
1932	86,347	115,811	186,764	48,008	436,030
1931	86,719	127,549	211,763	47,792	473,823
1930	75,432	120,034	242,612	48,428	486,506

[a] One cubic meter = 35.31 cubic feet.

Table 9 illustrates in how different a degree large and small oil operators contribute to the stabilization of the industry: the big firms (Malopolska, Galicia, Limanowa, Standard-Nobel), working principally Boryslaw, Bitkow and Rypne fields, produce 59.4 per cent of the country's oil production, and that in spite of a relatively smaller drilling effort on their part, while the small firms, assembled under the caption "Others," and operating principally upon the fields of the Jaslo district and that of Drohobycz outside of Boryslaw, contributed but 34.8 per cent of the total production at the expense of a drilling effort running up to

53.3 per cent of the total meterage drilled.[4] The least prominent part, as regards production, falls to the share of the Government-owned Polmin, which has contributed 9.1 per cent of the total meterage in the shape of a large number of wells drilled upon fields of small productiveness, such as Targowiska (field 3), Lipie (field 19), Dukla (near field 16). In 1937 the Jaslo district attained only one-half of the production volume of Boryslaw, in spite of having contributed as much as 50 per cent of the total meterage drilled in the country, and the fact that the least drilling effort was expended in the Boryslaw field (Tables 2 and 3).

TABLE 7.—*Gasoline Production, Poland*

Kilograms[a]

Year	Jaslo	District Drohobycz	Stanisławów	Total
1937	3,537,986	32,301,231	4,368,847	40,288,064 (+1%)
1936	3,476,616	31,833,221	4,571,970	39,881,807 (+1.01%)
1935	3,831,056	32,887,608	2,763,744	39,482,408
1934	4,436,585	33,349,333	2,952,171	40,738,069
1933	4,033,312	34,924,813	3,020,301	41,978,426
1932	2,521,915	33,257,716	3,053,045	38,832,676
1931	1,455,932	36,140,120	3,384,970	40,981,022
1930	197,240	34,903,905	3,392,505	38,493,650
NUMBER OF GASOLINE PLANTS				
1934	7	16	4	27
1935	6	14	5	25
1936	6	13	5	24
1937	7	15	6	28

[a] One kilogram = 2.205 pounds.

In carrying out a broad prospecting program upon the plains of northern and western Poland,[5] the Polish Geologic Survey commenced systematic regional magnetometric and gravimetric surveys. In 1937 40,000 sq. km. (9,884,000 acres) was covered by regional magnetometric surveys; 350 sq. km. (86,485 acres) by detailed surveys. Surveys made with Thyssen's gravimetric apparatus have covered in the eastern sector of the Polish lowlands 6000 sq. km. (568 points) and in the western sector 5000 sq. km. (360 points). Detailed surveys covered about 2000 sq. km. (220 points) and upon the Volhynian (Wołyń) area and in the Holy Cross Mountains (Góry Świętokrzyskie) 50 new gravity anomalies were ascertained by pendulum. Seismic surveys were carried out, according to plans furnished by the Geologic Survey, by the Pionier Company between the Vistula (Wisla) and San Rivers (1750 km. of cross sections) and in the Central Carpathians (80 km. of cross sections).

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[4] *Trans.* A.I.M.E. (1934) **107,** 405.

[5] *Trans.* A.I.M.E. (1935) **114,** 526.

The Pionier Company was organized in 1928 by eleven big petroleum firms, to do exploratory drilling in the Carpathians and in the Sub-Carpathian zone. Drilling in the Carpathians (8 wells) has failed to produce satisfactory results, while in the Sub-Carpathian zone a broad and accurately conducted geologic and, in part, seismic surveying campaign enabled the Pionier Company and also Polmin to attain satisfactory results when drilling for gas. Of wells drilled, so far, for gas by the Pionier Company, one (Rachiń) has been a failure, while a second one, near Kosów, upon a gaseous area tested beforehand by shallow drillings (to 300 m. depth), has not as yet been carried to completion.

TABLE 8.—*Ozokerite Production, Poland*

Kilograms[a]

Year	Boryslaw	Stanislawów (Dzwiniacz-Starunia)	Total
1937	310,465	155,445	465,910
1936	343,593	99,299	442,892
1935	300,945	68,163	369,108
1934	89,138	67,027	156,165
1933	326,648	39,368	366,014
1932	308,815	279,887	588,702
1931	110,050	152,253	262,303
1930	681,255	220,401	901,656

[a] One kilogram = 2.205 pounds.

TABLE 9.—*Participation by Some Big Companies in Production and Drilling during* 1936[a]

Company	Production, Per Cent	Drilling, Per Cent
Malopolska	41.4	26.0
Galicia	7.3	4.2
Gazy Ziemne	4.9	5.2
Limanowa	5.9	0.4
Polmin	1.0	9.1
Standard-Nobel (Vacuum)	3.3	0.9
Urycka Spólka	1.4	0.9
Others	34.8	53.3

[a] *Industrie minière du pétrole en Pologne* 1936 (1937) 315.

In connection with the activity of the Pionier Company upon the area lying between Daszawa and Nowy Sambor, the exploring wells in Wownia and Gaje Niżne (Malopolska), in Königsau (Pionier) and in Uherce (Polmin) permitted the structure of the terrain composed of the Upper Tortonian to be defined more accurately. As a result of this, in November 1937, a well drilled in Opary (Polmin 5) found at 395.5 to 399.5 m. depth a gas-bearing sandstone giving a free flow of approximately 100 cu. m. per min. of gas at 35 atm. pressure. After the positive results attained on the basis of surveys by the Pionier Company upon the areas of Kosów and Drohobycz (Opary), and by Polmin and Gazolina in the area of Tarnów-Dębica, it seems likely that the Pionier Company, as well as some of the latter's stockholders who have contracted for considerable tracts in the vicinity of Kosów and, more especially, between the Vistula (Wisla) and the San Rivers, may now engage more intensively in drilling than they have done hitherto.

A certain reawakening of interest, and in part the assistance granted by the Government from a special drilling fund, created to assist and encourage exploratory drilling, contributed to increase drilling activity in 1937.

Oil and Gas in Rumania

(New York Meeting, February, 1938)

The production of Rumania for 1937 amounted to 54,142,600 bbl., which is a decrease of 10,319,636 bbl., or 15.9 per cent over that of 1936. In all, 1,300,000 ft. were drilled during the year— an increase of 220,000 ft. over 1936.

Table 1.—*Oil and Gas Production in Rumania*

Line Number	Field, *Department*	Age, Years to End of 1937	Area Proved, Acres			Total Oil Production, Bbl.			
			Oil	Gas	Total	To End of 1937	During 1936	During 1937	Daily Average during Nov. 1937
1	Glodeni, *Dambovita*	40	400		400	549,800	9,100	9,800	30
2	Doicesti, *Dambovita*	25	200		200	22,600			
3	Draganeasa, *Prahova*	57	200		200	343,900			
4	Malul Rosu, *Dambovita*	34	200		200	5,800			
5	Colibasi, Resca, *Dambovita*	81	1,470		1,470	3,243,300			
6	Campina, *Prahova*	53	580		580	32,858,700	243,400	240,100	725
7	Bustenari, Runcu, *Prahova*	85	5,250		5,250	103,304,800	1,970,300	1,756,800	2,625
8	Scaiosi, *Prahova*	8	550		550	55,700	3,300	9,500	75
9	Copaceni, *Prahova*	33	250		250	1,132,500	44,100	103,000	300
10	Filipesti Padure, *Prahova*	27	250		250	2,037,300			
11	Pacureti, *Prahova*	38	150		150	233,200		3,500	80
12	Matita, *Prahova*	38	200		200	80,300			
13	West Gura Ocnitei, *Dambovita*	8	7,550		7,550	61,145,000	6,175,400	4,200,000	10,900
14	Gorgota-Ochiuri, *Dambovita*	24	1,250		1,250	38,949,700	2,057,500	2,330,000	7,500
15	Moreni, *Dambovita and Prahova*	34	3,700		3,700	307,288,000	19,366,000	17,050,000	49,000
16	North Moreni, *Prahova*	34	1,100		1,100	24,990,700	244,600	525,000	1,800
17	Piscuri, *Prahova*	10	450		450	19,693,400	2,387,600	4,420,000	43,800
18	Ditesti, *Prahova*	4			540	1,299,700	526,000	580,000	1,000
19	Calinesti, *Prahova*	3	75		75	22,300	10,000	12,000	300
20	Baicoi, Liliesti, Tintea, *Prahova*	76	750		750	34,233,400	638,700	1,880,800	7,680
21	Bucsani, *Dambovita*	4	3,900		3,900	29,255,600	16,522,500	7,800,000	11,300
22	Margineni, *Prahova*	2	20	880	900	281,500	130,700	150,800	8,255
23	Aricesti, *Prahova*	16	990		990	7,292,200	1,177,700	402,800	895
24	Boldesti, *Prahova*	10	4,890		4,890	55,533,200	10,482,470	10,088,300	26,250
25	Ceptura, *Prahova*	24	1,980		1,980	30,339,500	2,343,600	2,452,300	7,750
26	Orlea, *Prahova*	5	1,300		1,300	11,200			
27	Podenii Noi, *Prahova*	35	100		100	151‘100			
28	Udresti, *Prahova*	13	100		100	138,800			
29	Sarata-Monteorul, *Buzau*	68	260		260	3,611,800	57,300	55,300	150
30	Arbanasi, *Buzau*		400		400	15,418,300	306,400	321,300	876
31	Solont-Stanesti, *Bacau*	77	250		250	4,572,700	140,100	95,600	250
32	Zemes-Taslau, *Bacau*		170		170	4,616,600	134,900	140,500	370
33	Moinesti-Lucacesti, *Bacau*		275		275	2,704,900	106,300	98,500	185
34	Comanesti-Grozesti, *Bacau*		100		100	11,600	900	700	2
35	Tetcani-Campeni, *Bacau*		100		100	955,100	19,400	16,700	45
36	Eight Fields,[1] *Transylvania*								
37	Total		39,400	880	40,290	786,384,200	65,062,236	54,742,600	

[1] Sarmasel, Moinesti, Sincai, Saros, Nades, Bazna, Capsa-Mica, Daia.

Manuscript received at the office of the Institute Feb. 14, 1938. Information available through the courtesy of W. P. Haynes, Member A.I.M.E.

Boldesti, Moreni, and West Gura Ocnitei remained the most important fields of Rumania during 1937. Manesti was the only discovery during the year. Three gas wells were completed on this structure, but so far there are no indications of oil. Further work at Margineni has proved it to be of small importance, the area of production in the gas sands being small, and normal crude oil being limited to a narrow zone in one sand.

Important wildcats were drilled at Podenii Vechi and at Bratesti, but failed to open any new fields.

The most important development comprised deep drilling, which opened production in the Meotic at Tintea and along the south of the

Table 1.—(*Continued*)

Line Number	Total Gas Production, Millions Cu. Ft.	Number of Oil and/or Gas Wells							Depth, Average in Feet		Oil Production Methods at End of 1937					Pressure, Lb. per Sq. In.[d]		
			During 1937		At End of 1937						Number of Wells						Average at End of	
	To End of 1937	Completed to End of 1937	Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Gas Only	Total Producing	Bottoms of Productive Wells	To Top of Productive Zone	Flowing	Pumping	Gas-lift	Miscellaneous	Injection into Reservoir[c]	Initial	1936	1937
1		6				1		1	2,020	1,030		1				300		
2		4							1,930	1,770						600		
3		15							1,170	1,100						300		
4		10							1,000									
5		30							1,100									
6		280				68		68	1,200	700		28		40				
7		1,630	5		14	507		507	1,400	400	10	100		397		1,000		
8		6	1			2		2	1,800	1,450	1			1		280		100
9		16	2			5		5	2,200	700	1	4				180		160
10		57							3,800	3,250								
11		14	1		2	1		1	4,000	3,150	1					1,500		1,500
12		10							1,300									
13		320	8		10	94	4	98	5,900	5,400	10	45	12	31		160	150	70
14		263	26		8	72	2	74	4,000	3,700	12	62				2,000	400	300
15		1,184	47		20	491	7	498	5,000	4,500	25	280	91	102		3,000	300	200
16		380	6		5	47	1	48	4,000	3,500	5	32		11		2,000	800	700
17		125	27		31	82		82	4,000	3,500	10	44	16	12		1,500	700	450
18		9	3		2	4		4	7,300	6,900	4					700	600	600
19		4			4				5,700	5,300						1,600		1,200
20		465	16			77		77	7,800	6,900	9	28	4	36		2,000	500	450
21		145	43		8	111	1	112	7,100	6,500	23	39	50			1,500	600	450
22		16	5	2	5	5		5	6,600	6,100	3		2		G 1	2,700	2,300	2,000
23	1,343[2]	58	2		12	11	1	12	6,100	5,500	4	1	7			2,000	600	500
24	1,428[2]	147	21		31	97	1	98	7,900	6,900	37	10	51		G 1	1,600	900	800
25		196	16		32	78		78	3,300	2,400	10	59	7	2		1,400	600	500
26		7							8,400	7,600						1,000		
27		6							1,700									
28		2							2,400									
29		40				4		4	1,000	200		4						
30		180				87		87	1,000	200		87						
31		190	3			84		84	2,000	100		84						
32		60				33		33	1,000	200		33						
33		40				15		15	1,000	200		15						
34		20				2		2	2,200	1,000				2				
35		30				13		13	1,500	700		13						
36	140,000	70	2				25	25	1,500	600	25					750	450	450
37	140,000	6,035	234			1,991	42	2,033			190	969	240	634				

[c] Footnotes to column heads and explanation of symbols are given on page 313.

[2] From Dacio. Now abandoned.

salt between Baicoi and Tintea. The completions to date indicate high rates of production, and, because the area is competitive, development increased rapidly. As a result of the new development at Tintea, 1938 is expected to show an increase in Rumanian production.

The Bucsani field, which accounted for increases in 1936, has dropped rapidly and is now of minor importance. Boldesti continued active and was extended on the north and west. The Ceptura field showed renewed activities in the development of the north flank.

In the Moreni area, active development took place in drilling up the remaining area on the south flank and in the new area opened early in 1936 at North Piscuri. In this field, the Meotic has proved productive over a wider area than anticipated. The Dacic is also productive, but is

TABLE 1.—(*Continued*)

Line Number	Character of Oil, Approx. Average during 1937				Producing Rock						Number of Dry and/or Near-dry Holes to End of 1937	Deepest Zone Tested to End of 1937	
	Gravity A.P.I. at 60° F. Maximum	Gravity A.P.I. at 60° F. Minimum	Gravity A.P.I. at 60° F. Weighted Average	Base[e]	Name	Age[f]	Character[g]	Porosity[h]	Net Thickness, Average in Feet	Structure[i]		Name	Depth of Hole, Ft.
1			39	P	Meotic	Pli	S-Ss			Af	5	Meotic	2,600
2			39	P	Meotic	Pli	S-Ss		70	Af	3	Meotic	2,000
3				P	Meotic	Pli	S-Ss			AF		Meotic	1,200
4				P	Miocene	Mio	S-Ss			Af		Miocene	1,000
5				P	Meotic	Pli	S-Ss			Af		Meotic	1,100
6			41	P	Meotic	Pli	S-Ss			MF		Meotic	2,200
7	38	45	42	P	Meotic and Miocene	Pli, Mio	S-Ss	20		MF		Oligocene	7,800
8			40	P	Meotic	Pli	S-Ss			MF	3	Meotic	1,800
9			41	P	Meotic	Pli	S-Ss			AF		Meotic	2,200
10			39	P	Meotic	Pli	S-Ss			A	28	Deep Meotic	6,400
11	26	68	52	M	Dacic, Pontic, Meotic	Pli	SsS-Ss	15		Af		Meotic	4,000
12				P	Meotic	Pli	S-Ss			Af		Meotic	1,300
13			33	P	Meotic	Pli	S-Ss	15		SA	14	Miocene	6,500
14			33	M	Dacic and Meotic	Pli	SsS-Ss	20		SA	45	Miocene	4,100
15	21	35	33	M	Dacic and Meotic	Pli	SsS-Ss	15		SA	120	Miocene	7,000
16	28	39	33	M	Dacic and Meotic	Pli	SsS-Ss	15		SA	80	Miocene	7,000
17	26	40	33	M	Dacic and Meotic	Pli	SsS-Ss	15		SA	7	Miocene	4,000
18			33	P	Meotic	Pli	S-Ss			SA	2	Meotic	7,300
19			33	P	Meotic	Pli	S-Ss			SA	1	Meotic	5,700
20	26	45	39	M	Dacic and Meotic	Pli	SsS-Ss	18		SA	153	Meotic	8,000
21	36	44	38	P	Meotic	Pli	S-Ss			Af	21	Meotic	7,300
22	37	65	39	P	Meotic	Pli	S-Ss			Af	4	Meotic	6,600
23	32	48	35	P	Meotic	Pli	S-Ss	18		Af	15	Meotic	8,100
24	34	66	37	P	Meotic	Pli	S-Ss	13		Af	6	Meotic	9,100
25	31	35	34	P	Meotic	Pli	S-Ss	13		A	17	Meotic	5,800
26			34	P	Meotic	Pli	S-Ss			A	6	Meotic	11,000
27				P	Meotic	Pli	S-Ss			SA		Meotic	7,900
28			34	P	Meotic	Pli	S-Ss			Af		Meotic	2,400
29			38	P	Meotic	Pli	S-Ss	13		A		Meotic	1,200
30			38	P	Meotic	Pli	S-Ss	13		A		Miocene	2,800
31			43	P	Oligocene	Olig	S-Ss			AF		Oligocene	3,050
32			43	P	Oligocene	Olig	S-Ss			AF		Oligocene	1,500
33			43	P	Pliocene and Oligocene	Pli, Olig	S-Ss	10		AF		Oligocene	3,500
34			44		Oligocene	Olig	S-Ss	10		AF		Oligocene	2,200
35			44		Miocene	Mio	S-Ss			A		Miocene	3,300
36					Sarmatic	Mio	S-Ss			D		Miocene	3,000
37													

of minor importance. Dacic production in the main Moreni field was extended one kilometer east.

In Transylvania no additional gas fields were discovered.

Exploration has been greatly handicapped by the mining law. During 1936, the mining authorities, realizing the effect of unwise legislation in retarding the discovery of new production, recommended a revision of the law. This was finally accomplished in March 1937, but the result was the opposite to that hoped for. Exploration was further hindered rather than encouraged. As a result, there was a complete stoppage of requests for exploration lands. When the situation was realized fully, a revision of the law was proposed to permit the explorer to retain for exploitation all land proved up to about 6000 acres on areas situated more

TABLE 2.—*Summary of Drilling Operations in Rumania*

SURFACE FORMATION, LEVANTINE

	Area	Total Depth, Ft.	Deepest Horizon Tested	Drilled by	Initial Production per Day	Choke or Bean, Fractions of an Inch	Pressure, Lb. per Sq. In.		Remarks
					Gas, Millions Cu. Ft.		Casing	Tubing	
	WELLS DRILLING ON DEC. 31, 1936								
1	Floresti No. 1........	1,795		Romano Americana					Drilling for Meotic
2	Podenii Noi No. 1806..	5,069		Steaua Romana					Drilling for Meotic
3	Podenii Vechi No. 1...	591		Unirea					Drilling for Meotic
	IMPORTANT WILDCATS DRILLED IN 1937								
4	Floresti No. 1........	7,500	Pontic	Romano-Americana					Drilling abandoned
5	Podeni Vechi No. 1...	7,881	Meotic	Unirea					Dry
6	Manesti No. 1.........	6,818	Meotic	Unirea				2,500	Gas
7	Manesti No. 2.........	5,053	Dacic	Unirea					Drilling abandoned
8	Manesti No. 1.........	6,828	Meotic	Steaua-Romana	4	⅙	1,450	1,600	Gas
9	Manesti No. 1.........	6,460	Meotic and Dacic	Romano-Americana	0.9	⅙	1,550	900	Dry and gas
10	Bratesti No. 1........	5,276	Meotic	Astra-Romana					Dry
	WELL DRILLING ON DEC. 31, 1937								
11	Podeni Noi No. 1806..	8,275	Pontic	Steaua Romana					Drilling for Meotic

	In Proven Fields	Wildcats
Number of wells drilling Dec. 31, 1937..................................	63	7
Number of oil wells completed during 1937..............................	208	6
Number of gas wells completed during 1937..............................	8	2
Number of dry holes completed during 1937..............................	25	2
Number of wells drilling abandoned 1937................................	10	2

than 20 km. from developed areas. Immediately a number of requests were made for concessions of this type but none have been granted.

The new law discriminates between companies with Rumanian and with foreign capital. Financially, the companies continued to work under great difficulties. Because of the slow operation of clearing conventions, large sums of money are tied up for long periods. The State increased appreciably the freight rates on products for export. Difficulties continued in obtaining import permits, especially for oil-well machinery from America.

Russian Oil Industry in 1937

By Basil B. Zavoico,* Member A.I.M.E.

(New York Meeting, February, 1938)

During 1937 the Russian oil industry made very satisfactory progress in its exploration branch and added considerably to its proven reserves in the older producing districts, while several entirely new potential areas were opened for development by discovery wildcats. The exploitation of known fields, however, suffered greatly from internal political difficulties, referred to as "sabotage," and was also seriously handicapped by the requirements for national defense under the duress of a grave international situation. More particularly, the necessity for preparing for a major war resulted during 1937 in short-rationing of the oil industry in its iron, steel and rubber requirements, affecting quantitatively drill pipe, casing, tubing and the rubber equipment of automobiles, and qualitatively much of the oil-field machinery for which it was either impossible or difficult to obtain iron or steel of required specifications, which necessitated manufacture of heavier and unwieldy equipment and caused directly and indirectly an unavoidable major curtailment of drilling operations below the planned footage. War-preparation measures during 1937 also required accumulation of a large gasoline reserve in the Vladivostok area and inasmuch as shipments from California can be made much more cheaply than from Caucasian refineries, either by tank cars across Siberia or by tankers via Suez Canal and Indian Ocean, some 2,000,000 bbl. of gasoline was imported from the United States in the past year, resulting in a decline of 46.98 per cent in net exports of all petroleum products from Russia below the 1936 net export volume, which is the lowest level since 1925.

Production of crude oil during 1937 is estimated at 212,742,000 bbl. as compared with 202,543,700 bbl. produced in 1936, an increase of 5.04 per cent, but 11 per cent below the planned output. There were no major readjustments as to the source of crude-oil production, Baku district still accounting for the largest share; that is, 77.21 per cent of the total. Exploration operations were outstandingly successful during the past year, major discoveries having been made on the Apsheron Peninsula, in Grozny and Maikop-Kuban districts, in Ural-Permian Basin, in Middle Volga-Samara district and other areas.

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TABLE 1.—*Production of Crude Oil in Russian Oil Fields from* 1821 *to* 1937

THOUSANDS OF BARRELS

Year	Trans-Caucasus, Baku and Georgia (F: 7.28[1])	N. Caucasus, Grozny (F: 7.19)	NW. Caucasus		Central Asia	
			Maikop (F: 7.33)	Kuban (F: 7.33)	Turkmenneft (F: 7.41)	Sredazneft (F: 7.20)
1821–71	2,307.8	54.6		266.8		
1872	190.0	5.0		2.2		
1873	484.8	3.6		4.4	4.4	
1874	593.3	4.3		11.7	11.9	
1875	762.9	3.6		27.9	169.7	
1876	1,330.1	5.0		8.1	45.2	
1877	1,801.8	6.5		11.7	23.7	
1878	2,394.4	9.3		5.1	24.5	
1879	2,872.0	15.8		8.1	34.8	
1880	2,499.2	19.4		11.0	34.8	
1881	4,777.9	16.5		4.4	28.9	
1882	5,955.0	15.1		40.3	12.6	
1883	7,152.7	13.7		44.7	5.2	
1884	10,631.7	9.3		97.5	30.4	
1885	13,717.0	8.6		135.6	6.7	0.7
1886	13,658.0	10.8		124.6	8.9	0.7
1887	16,943.5	13.7		125.3	98.6	1.4
1888	21,734.4	19.4		150.3	34.8	0.7
1889	23,649.8	33.1		166.4	34.8	
1890	27,206.1	44.6		217.0	34.8	
1891	32,749.8	53.2	2.2	128.3	21.5	0.7
1892	33,911.0	36.7	2.9	166.4	23.7	0.7
1893	39,171.5	985.7	2.2	61.6	25.2	
1894	35,005.2	616.9	1.5	145.9	10.4	0.7
1895	45,545.1	3,343.4	1.5	159.8	10.4	1.4
1896	46,483.5	2,768.9	1.5	167.9	11.1	0.7
1897	50,588.0	2,161.3	2.9	170.1	10.4	0.7
1898	58,339.7	2,097.3	0.7	142.9	41.5	0.7
1899	62,123.9	2,914.8	2.9	99.7	34.8	0.7
1900	71,821.6	3,610.1	0.7	31.5	44.5	1.4
1901	79,925.7	4,086.8	2.9	31.5	74.1	1.4
1902	76,466.9	4,025.7	2.2	47.6	64.5	4.3
1903	71,738.6	3,957.4	2.2	34.5	36.3	2.9
1904	74,122.0	4,933.8	1.5	16.1	72.6	56.2
1905	49,387.5	5,193.3	11.0		106.0	242.6
1906	54,246.9	4,580.7	10.3		72.6	509.8
1907	57,779.9	4,664.9	13.9	5.9	99.3	381.6
1908	56,894.7	6,137.4	18.3	5.9	155.6	327.6
1909	60,446.6	6,725.5	90.9	7.3	222.3	100.1
1910	59,926.8	8,729.4	162.7	5.9	956.6	205.2
1911	54,872.3	8,859.5	944.1	6.6	1,615.4	294.5
1912	56,776.7	7,710.6	1,103.9	12.5	1,578.3	280.1
1913	55,523.8	8,679.8	583.5	64.5	959.6	166.3
1914	51,698.2	11,600.3	492.6	46.9	607.6	236.9
1915	54,464.6	10,390.3	937.5	77.0	548.3	220.3
1916	57,468.3	12,108.0	264.6	101.2	422.4	220.3
1917	48,382.9	12,619.9	305.7	125.3	363.1	252.7
1918	24,936.9	2,993.9	451.5	140.0	363.1	207.4
1919	27,220.1	4,316.2	358.4	86.5		155.5
1920	21,221.2	6,247.4	115.1	29.3		120.2
1920–21	17,889.1	8,651.0	240.4	74.8	34.1	126.0
1921–22	21,930.3	10,331.3	310.1	89.4	53.4	123.8
1922–23	26,012.9	10,809.4	321.8	56.4	42.2	110.2
1923–24	30,800.2	11,727.6	384.8	68.2	38.5	120.2
1924–25	34,487.5	14,572.0	484.5	118.7	45.2	136.1
1925–26	40,666.8	17,341.6	457.4	92.4	84.5	133.9
1926–27	50,204.3	21,726.0	490.4	109.2	74.1	159.1
1927–28	55,746.6	25,713.6	651.6	123.1	57.8	203.8
1928–29	63,812.8	31,945.2	1,023.3	120.2	65.2	171.4
1929–30	74,860.2	43,550.5	3,324.9	101.9	86.0	282.2
1930 (Sp. Quarter)	21,484.0	15,802.2	381.2	29.3	39.3	100.8
1931	96,229.2	57,979.4	3,889.3	175.9	103.0	544.3
1932	89,089.0	55,432.7	6,666.6	151.0	251.2	442.8
1933	111,964.9	34,959.2	4,330.6	124.6	1,146.3	354.2
1934	140,088.3	24,231.7	6,877.0	118.0	118.6	424.8
1935	141,257.5	22,793.0	8,642.1	114.3	2,487.5	1,154.9
1936	158,300.0	21,500.0	7,650.0		2,850.0	1,200.0
1937 annual	164,250.0	20,800.0	10,000.0		3,470.0	1,387.0
1937 daily	450.0	57.0	27.4		9.5	3.8
1938 annual[3]	165,000.0	19,500.0	16,000.0		4,000.0	1,500.0
1938 daily[3]	452.1	53.4	43.8		11.0	4.1
Total (less 1938)	3,068,975.9	607,327.4	67,266.9		20,242.8	11,172.6

[1] *F* means conversion factor from metric tons into barrels according to average crude gravities in each district.

[3] Author's estimate; official plan anticipates production of 244,000,000 bbl., or 668,493 bbl. per day, during 1938.

TABLE 1.—(*Continued*)

Year	Emba (F: 6.97)	Crimea (F: 7.28)	Sakhalin (F: 6.82)	Ural		Middle Volga (Jiguli) (F: 7.30)	Total
				Bashkiria (F: 7.19)	Kama (F: 6.97)		
1821–71		1.5					2,630.7
1872							197.2
1873							497.2
1874		2.2					623.4
1875		2.2					966.3
1876		0.7					1,389.1
1877		0.7					1,844.4
1878							2,433.3
1879							2,930.7
1880							2,564.4
1881							4,827.7
1882							6,023.0
1883							7,216.3
1884							10,768.9
1885		3.6					13,872.2
1886		0.7					13,803.7
1887							17,182.5
1888							21,939.6
1889		0.7					23,884.8
1890		3.6					27,506.1
1891		2.2					32,957.9
1892		0.7					34,142.1
1893							40,246.2
1894							35,780.6
1895							49,061.6
1896							49,433.6
1897							52,933.4
1898							60,622.8
1899							65,176.8
1900							75,509.8
1901							84,122.4
1902							80,611.2
1903							75,771.9
1904							79,202.2
1905							54 940.4
1906							59,420.3
1907							62,945.5
1908							63,539.5
1909							67,592.7
1910							69,986.6
1911	125.5						66,717.9
1912	116.4						67,578.5
1913	819.7						66,797.2
1914	1,901.4						66,583.9
1915	1,899.3						68,537.3
1916	1,774.6						72,359.4
1917	1,783.6						63,833.2
1918	1,016.2						30,109.0
1919	185.4						32,322.1
1920	211.2						27,944.4
1920–21	400.1						27,415.5
1921–22	933.3						33,771.6
1922–23	927.7						38,280.6
1923–24	874.7						44,014.2
1924–25	1,358.5						51,202.5
1925–26	1,520.2						60,296.8
1926–27	1,766.9						74,530.0
1927–28	1,741.1						84,237.6
1928–29	1,875.6		120.0		4.2		99,137.9
1929–30	2,381.6		509.5		39.0		125,135.8
1930 (Sp. Quarter)	584.1		215.5		11.2		38,647.6
1931	2,270.1		911.8		43.2		162,146.2
1932	1,721.6		1,247.4	33.1	41.8		155,077.2
1933	1,368.9		1,339.4	147.4	100.4		155,835.9
1934	1,684.0		1,649.1	450.1	85.0		175,726.6
1935	1,912.6		1,632.0	2,917.7	55.8		182,967.4
1936	2,100.0		2,100.0	6,780.0	63.7		202,543.7
1937 annual	2,900.0		2,700.0	7,000.0	135.0	100.0	212,742.0
1937 daily	7.9		7.4	19.2	0.4	0.5[2]	582.9
1938 annual[3]	3,000.0		3,200.0	7,500.0	219.0	500.0	220,419.0[3]
1938 daily[3]	8.2		8.8	20.5	0.6	1.4	603.9
Total (less 1938)	38,154.3	18.8	12,424.7	17,328.3	579.3	100.0	3,843,591.0

[2] Estimate over part of year only.

As already indicated, drilling operations lagged considerably, falling 37 per cent under the plan in the exploitation branch of the industry and 32.2 per cent under the plan in the exploration branch, making the quick assimilation of newly discovered reserves impossible.

SOUTHEAST CAUCASUS

On the Apsheron Peninsula, the Azneftcombinat Trust was remarkably successful in finding both vertical and horizontal extensions to the older fields. The older Balakhani-Ramani-Sabunchi (Leninneft) area was extended one mile in the direction of Kala, apparently proving that this major structural axis branches out at Balakhani, the Sabunchi plunging nose being part of Surakhany, Kara-Chukhur and Zykh axis trending south from Balakhani, while Ramani branch trends due east. Also, there are some suggestions that in turn the axis of the Surakhany structure forms two branches, one continuing to Kara-Chukhur and Zykh, the other trending southeast in the direction of Cape Goisan. Deeper drilling to the pre-Kirmaku zone of the "Productive Series" on the south end of Surakhany has proved additional major reserve, the deepest wells in Russia producing in this field at around 8600 ft. about 2000 to 3000 bbl. per day initially on ¾-in. choke. Kara-Chukhur field was also considerably extended during the past year. Major and unexpected extension to the north-northeast appears certain in the Bibi-Eibat field, where large oil wells were brought in from the pre-Kirmaku sands at the foot of the high Apsheron limestone escarpment, and at this writing test wells are being drilled on the escarpment itself. Areal extensions of Artem Island field increased appreciably the reserves of that pool. Apparently a structure of major magnitude was uncovered offshore at Mardakiani, possibly on Artem Island trend, and it is due to be tested shortly by the drill. Elsewhere on the Apsheron Peninsula, in the Alyat-Saliani area and in Georgia nothing of major importance was noted in 1937, the more distant districts being handicapped by the ineffective service of supplies. In order of importance the fields of the Azneftcombinat early in 1938 ranged as listed in Table 2. In general it may be stated that while last year there was some doubt as to the ability of the Azneftcombinat to increase, or even maintain, its production, the areal and depth extensions made to older fields during 1937 apparently assure this primary Russian producing region of continued high rate of output for at least the immediate future. The problem before the management of the Baku fields is to be able to maintain the present rate of production by gradual development of the known horizons in the old fields, more particularly the Kirmaku sands, while searching for new major fields and exploring for probable pre-Pliocene reserves in old fields. The Azneftcombinat has a fund of "inactive" wells, about 2400, a considerable proportion of which undoubtedly could be brought back to production as small pumpers making around 50 bbl. per day, thus constituting a possible production reserve of from 50,000 to 75,000 bbl. per day. The repairs of "inactive" wells are greatly complicated, however, by lack of necessary equipment, while the "sabotage" and the possible damage to professional reputation with its consequences often resulted in classification of oil wells and of dry holes, respectively, as temporarily "inactive" wells, thus making the rehabilitation work a major and complicated undertaking.

TABLE 2.—*Producing Oil Fields of the Azneftcombinat, Southeast Caucasus*

Field	Bbl. per Day	Per Cent
Balakhani-Sabunchi-Ramani (Leninneft)	100,000	22.22
Bibi-Eibat (Stalinneft)	87,000	19.33
Kala (Azizbekoffneft)	75,000	16.67
Surakhany (Ordjonkidzeneft)	70,000	15.56
Lok-Batan and Puta (Molotovneft)	45,000	10.00
Kara-Chukhur and Zykh (Kaganovichneft)	44,000	9.78
Artem Island (Artemneft)	15,000	3.33
Binagadi and Sulu-Tepe (Kirovneft)	8,500	1.89
Kergez (Kergezneft)	4,000	0.89
Alyat (Alyatneft)	1,500	0.33
	450,000	100.00

NORTHEAST CAUCASUS—GROZNY AND DAGESTAN

The Grozneftcombinat was not as successful as the Azneftcombinat in blocking out new reserves, and while several important new discoveries were made their assimilation was delayed by the lack of effective organization, of roads, of pipe lines and of supplies. In this district the recent Russian trend of very satisfactory geological work and very slow progress of the drilling and the production departments was particularly noticeable.

The area of Grozny and Dagestan oil fields is associated with the foothills of the Caucasian Ridge, and its surface geology is not complicated, making the discovery of favorable structural features relatively easy. All the producing fields in this district are associated either with the Terski (north) and Sunjenski (south) ranges of hills, or with their extensions in Dagestan, all these paralleling the main Caucasian Ridge. The Old and the New Grozny fields are in the eastern part of the Sunjenski Range, while Malgobek and Voznesenski fields are part of the Terski Range. Of the newer prospective semiproven areas Shali and Benoi are part of the Sunjenski Range, while Gorski Mountain, Taimaz-Kala, Mujim-Birk and Gudermes are associated with the Terski Range. Farther north geophysical exploration has established the presence of the third parallel range, which, however, is buried and is known as the "Edessi Anomaly"; it is to be explored by drill in the immediate future.

The Old and the New Grozny fields are very definitely past their peak and except for gradually diminishing output to be secured almost entirely by pumping and by gas-lift these two pools cannot be counted upon for sizable production. Of the newer fields Voznesenski has proved to be somewhat of a disappointment, but Malgobek has been developed into a medium sized field with a production of around 25,000 bbl. per day, though even in this relatively new field around 80 wells are already on "inactive" list. Of the new discoveries, Gorski Mountain appears most promising, with recent wells being completed for 1500 to 4000 bbl. per day initially from around 3500 ft. Near Gudermes a new field was discovered in September 1937; well No. 7 flowing 2160 bbl. per day from 3400 feet.

In Dagestan the recent discoveries in Izberbash and in Achi-Su have been almost entirely neglected and instead of the planned production of 20,000 bbl. per day during 1937 only 4000 bbl. per day is being actually produced.

In general the Grozneftcombinat has been consistently the most backward of all Russian major oil-producing units, and complete reorganization appears to be necessary before any improvement in its record may be expected. There are now 1800 "inactive" wells in Grozneft.

NORTHWEST CAUCASUS—MAIKOP-KUBAN

The Maineft Trust, operating in Maikop-Kuban district, was one of the most successful subdivisions of the Russian oil industry during 1937. This district produced 21,000 bbl. per day during 1936, about 27,400 bbl. per day during 1937, and early in 1938 increased its output to 42,000 bbl. per day, making 123 per cent of the plan. Discoveries in this territory were made in the known Kalujski-Apsheronski trend and included such apparently outstanding new fields as Asphalt Mountain, Kura-Tzetze and Shirokaia Balka. Drilling operations, however, in Maikop-Kuban area were, as elsewhere, far behind the plan, falling about 50 per cent short of the projected footage; therefore the more satisfactory performance of the producing division of Maineft apparently was due to large flowing wells brought in during 1937. But even though the Maikop-Kuban district is easily accessible, and its terrain is that of a rolling prairie, the servicing of new fields was on a primitive scale and official Soviet organs complained repeatedly that new fields there have no roads, no water, no equipment and no pipe lines, and that the light crude oil is being kept in earthen storage. In the older fields of Maineft some 1700 wells are on "inactive" list.

URAL-VOLGA BASIN

During 1937 the most important regional discoveries and developments in Russia took place in the Ural-Volga Basin, proving, in effect, that the whole area from Volga River on the west and Ural Mountains on the east, the Perm Province on the north and the Emba salt-dome basin on the south, is one major oil province embracing roughly 300,000 square miles.

On the north end, near the 1929 discovery at Chusovski Gorodki, a new field was discovered at Krasnokamsk, currently capable of producing about 10,000 bbl. per day, in an area that formerly was not rated highly because of the failure of Chusovski Gorodki field to come up to expectations. Farther south the Ishimbaevo field was further developed but its output proved to be disappointing, owing undoubtedly to the forced rate of production during 1936. In 1937 Ishimbaevo produced only about 20,000 bbl. per day, as compared with the planned output of around 40,000 bbl. per day. At the close of 1937 there were in Ishimbaevo some 170 completed "oil" wells, of which only about 100 were actually producing, and while in 1936 fully 80 per cent of the production was derived from flowing wells, in 1937 the production from flowing wells dropped to 30 per cent of the total and by the end of the year was down to 15 per cent. The decline of flowing production apparently caught the field management by surprise because as yet Ishimbaevo is not prepared to lift the crude oil efficiently by mechanical means. On the Volga River the Samarski Luki range of hills, mentioned in last year's report, was definitely proven for large flush production at several localities: near Syzrian, in the oil field by the same name, some 12 oil wells were completed producing at the end of the year about 500 bbl. per day; farther east promising showings were encountered at Troekurov; while at Yablonovo a 1500-bbl. flowing well was brought in in December 1937; and at Zolny favorable results were also indicated. Considering that the new district of Samarski Luki is on the main water route of Russia, its development has been ridiculously slow, explainable only by the inability of the Government to spare engineers, skilled technicians and equipment from the older oil districts.

Between Samarski Luki and Ishimbaevo most favorable indications and actual production of crude oil were obtained in wildcat wells at Buguruslan and at Tuimaza, proving as petroliferous the intervening area, some 300 miles wide.

Elsewhere in Russia potentially the most important discovery was made near Romni, in Ukraina, where a salt dome was found apparently proving a new interior salt-dome basin; the discovery well, also showing a little crude oil, making 5 to 10 bbl. per day, a most encouraging indication. In Central Asia, in Soviet Socialistic Republics of Turkmen (Turkmenneft), Uzbek and Tadjik (Sredazneft), some progress apparently was made during 1937, but the development of this province continued to be distinctly on a small scale. The Emba (Embaneft) salt-dome province was again disappointing, and even though the number of proven and possible salt domes in this area is very large the magnitude of the crude oil reserve in Emba remains to be proved, with more evidence at this time that this reserve is distinctly mediocre. Nothing of great importance was noted in Sakhalin, though production on this island is gradually increasing, being now about 9000 bbl. per day on Russian leases and about 5000 bbl. per day on the Japanese concessions, exact figures not being available because the island lies in the trouble zone of the Pacific.

Because of the slowness of assimilation of new reserves in Russia, it is obviously impossible to estimate even approximatly the newly blocked out reserves in 1937. With the exception of extensions made in the Baku district and the new fields brought in in Maikop-Kuban area, all other new discoveries must necessarily be given only a nominal reserve, since there are no data available as to the extent of new producing fields, stability of oil production, etc. It is the author's tentative estimate that newly blocked out oil reserve in Russia during 1937, in new fields and in extensions, was about 500,000,000 bbl., as compared with the 1937 production of 213,000,000 bbl., suggesting that the proven blocked-out reserve of Russia at the close of 1937 was 4,787,000,000 barrels.

TABLE 3.—*Exports from U. S. S. R.*

BARRELS

Petroleum and Products	1933	1934	1935	1936	1937
Crude and fuel oil	16,320,000	14,110,000	12,050,000	9,350,000	5,520,000
Gasoline: gross exports	12,350,000	11,850,000	7,970,000	5,610,000	3,870,000
Imports				420,000	2,000,000
Net exports	12,350,000	11,850,000	7,970,000	5,190,000	1,870,000
Kerosene	4,010,000	3,450,000	3,170,000	2,350,000	1,290,000
Lubricating oils	1,810,000	1,780,000	2,420,000	2,290,000	1,490,000
Total	34,490,000	31,190,000	25,610,000	19,180,000	10,170,000
Decline from preceding year, per cent		9.57	17.89	25.11	46.98
Daily rate, bbl.	89,200	85,500	70,250	52,500	27,800
Percentage of production	22.1	17.6	14.0	9.5	4.8
Asphalt and paraffin, tons	60,000	224,000	38,200	8,000	

REFINING

During 1937 Russian refineries ran to stills 194,000,000 bbl., 8.98 per cent above 1936 runs but 11.5 per cent below the plan. Production of gasoline in Russia reached about 38,000,000 bbl. during 1937, or 19.6 per cent of runs to stills; of this total, 40 per cent was straight-run and 60 per cent was from cracking plants, while in addition about 1,000,000 bbl. of gasoline was produced in natural gasoline plants. Production of kerosene during 1937 was about 43,500,000 bbl., or 22.4 per cent of the runs to stills. Refining operations and new construction continued to be centered in Caucasus, principally in Baku, Grozny and Batum, with smaller plants at several strategic points of Russia.

Exports

The decline in net exports during 1937 (46.98 per cent as compared with the 1936 export volume) was due partly to the increased domestic demand and partly to the economic necessity for importing gasoline supplies into the Vladivostok area from California. Table 3 presents export statistics from 1933 to 1937.

Conclusions

The difficulties that face the Soviet Government in its management of the oil industry have led this industry into a very involved situation and its solution is necessarily dependent upon either the correction or the improvement of the basic factors. Insufficient supplies are partly due to the preparation for war necessitated by the present international situation but even the distribution of available supplies and equipment is greatly delayed. The poor grade of much of the equipment in combination with poor supervision and attention to such equipment results in serious breakdowns, which, together with unsatisfactory distribution of replacements, results in extensive shutdowns, which more particularly affect the uncased drilling wells and hence greatly disrupt the projected plans. The distribution of equipment is handled so poorly that a large number of completed oil wells are shut down for lack of production facilities. This situation affects particularly the wells that stop flowing, for which mechanical lifting equipment becomes necessary, the total number of potential oil wells carried on the books as "inactive" at the end of 1937 being around 5500.

It is extremely doubtful whether Soviet Russia would have been able to increase and maintain its production at the present levels without the great reserve available in Baku district, which has been and probably will continue to be the principal base of operations for many years to come. With increased domestic demand for petroleum products, the exports from Russia probably will be entirely discontinued within the next few years, and unless much greater production is obtained on Sakhalin Island or on the Siberian mainland considerable imports may be necessary from California, particularly if the present war fears persist.

Petroleum and Gas in Trinidad during 1937

(New York Meeting, February, 1938)

The first production on the Island of Trinidad was discovered 29 years ago; 13,275 acres were proved for oil and gas to the end of 1937, and 145,076,700 bbl. was produced from 2661 wells, or 10,928 bbl per acre.

The production of oil in 1936 was 13,237,030 bbl. and in 1937 a new peak of 15,498,350 bbl. was reached. During November 1937, the daily average production was 43,350 bbl., or 35 bbl. per well, while the maximum gas production was 45 million cubic feet daily.

Two hundred fifty wells were completed during 1937 and 15 abandoned. At the end of last year, 800 wells had been temporarily shut down, 1235 were producing oil and gas, and 2 were producing gas only. Six hundred seventy-nine dry wells had been drilled to the end of 1937.

At the end of November 1937, the following oil-producing methods were in use: 395 wells flowing, 491 pumping, 97 on air-gas lift and 252 wells miscellaneous. There were no flooding operations.

The oil is produced from the Miocene and Eocene and is of both asphalt and paraffin base. The gas produced averaged approximately 1050 B.t.u. per cu. ft. with 0.8 gal. of gasoline per 1000 cubic feet.

Manuscript received at office of the Institute Feb. 8, 1938.

Petroleum Development in Venezuela during 1937*

(New York Meeting, February, 1938)

PRODUCTION of crude oil in Venezuela for the year 1937 was 186,653,916 bbl., as compared with 155,228,982 bbl. produced in 1936, an increase of almost 31,500,000 bbl. The oil-field strike, which started on Dec. 14, 1936, lasted until Jan. 25, 1937, when a total of 10,000,000 bbl. of production was estimated to have been lost (5,750,000 bbl. in 1936 and the remainder in 1937). Of the total of 186,653,916 bbl. produced in 1937, the Lagunillas field contributed 45.6 per cent, a drop of approximately 10 per cent under 1936 figures; Tia Juana, 14.3 per cent; Quiriquire field, 14.0 per cent; La Rosa area, 13.3 per cent and the Mene Grande field, 7.6 per cent, these being the five leading contributors of the year's production. Detailed production figures by fields and by companies are shown on Table 1. Of the total production of Venezuela the following four major companies accounted for the greater proportion: Standard of Venezuela and Lago Petroleum Corporation together, 48.3 per cent; Shell, 37.4 per cent and Venezuela Gulf, 14.0 per cent. At the end of the year, 2491 wells were producing, of which number 1291 wells were pumpers, or about 52 per cent.

PRODUCTION

The accompanying statistics of production record of Venezuela oil fields from its inception to Dec. 31, 1937, shown on Table 2, indicates that the cumulative production reached 1,503,283,228 bbl. In order of importance, Lagunillas leads all the fields, having accounted for about 50 per cent of Venezuelan production, followed by La Rosa area, which produced about 21 per cent; Mene Grande, which produced about 13 per cent, and Quiriquire, which produced 6.5 per cent.

Table 3 shows the age of each field. Mene Grande is the oldest, having produced for 24 years; Tarra is next, 21½ years old, and El Mene third, 17½ years. The gravity of the crude from the various fields, also shown on Table 3, remained unchanged, the only addition being the new Tia Juana field, which averages 15.6° A.P.I.

Table 4 shows the method of production by fields as of Jan. 1, 1938; at the end of the year 2491 wells were producing, compared with 2005 wells producing at the beginning of 1937, or an increase of 486 wells. The completions for the year reached 512. Of the 2491 wells producing crude oil, 1291 wells, or approximately 52 per cent, were pumping, 925 (approximately 37 per cent) were flowing naturally and 275 (11 per cent) were on

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[*] Compiled by Basil B. Zavoico from information furnished by C. C. McDermond and others. Manuscript received at the office of the Institute Feb. 12, 1938.

TABLE 1.—*Production of Crude Oil in Venezuela, 1937*

	La Rosa Field				Tia Juana Field				Lagunillas				Mene Grande	El Mene	Media
	Lago	Gulf	V.O.C.	Total	Lago	Gulf	V.O.C.	Total	Lago	Gulf	V.O.C.	Total	C.P. Co.	B.C.O	B.C.O.
January	810,895	188,370	172,135	1,171,400	39,645		969	40,614	2,518,044	883,619	1,458,745	4,860,408	712,786	38,559	20,737
February	843,423	345,771	802,845	1,992,039	53,224		6,875	60,099	3,228,785	1,266,255	2,726,913	7,221,953	1,077,120	43,620	17,787
March	997,379	394,597	843,324	2,235,300	71,099	21,883	82,588	175,570	3,829,977	1,467,294	3,134,248	8,431,519	1,229,007	49,866	17,641
April	998,041	399,064	714,598	2,111,703	70,882	233,010	295,378	599,270	3,713,486	1,296,560	2,896,655	7,906,701	1,121,759	47,615	14,253
May	1,042,295	415,028	634,856	2,092,179	230,735	639,205	589,920	1,459,860	3,807,035	1,281,635	2,760,246	7,848,916	1,172,081	46,431	12,218
June	1,030,441	386,214	610,471	2,027,126	576,117	935,355	927,555	2,439,027	3,545,108	1,202,495	2,740,247	7,487,850	1,248,829	45,113	11,293
July	985,293	414,998	791,881	2,192,172	777,802	1,110,656	1,193,980	3,082,438	3,705,299	1,204,455	1,929,287	6,839,041	1,264,022	46,659	12,374
August	1,054,706	402,744	767,162	2,224,612	1,046,249	1,129,543	1,482,522	3,658,314	3,701,219	1,171,449	2,042,264	6,914,932	1,295,532	45,868	9,793
September	956,766	371,598	752,561	2,080,925	1,335,720	1,060,056	1,580,386	3,976,162	3,470,343	1,111,883	2,460,480	7,042,706	1,275,529	44,227	9,465
October	1,113,855	375,741	782,654	2,272,250	1,425,525	965,578	1,778,365	4,169,468	3,013,013	1,136,131	2,726,024	6,875,168	1,293,746	45,202	9,205
November	1,121,339	347,870	775,350	2,244,559	1,312,258	771,613	1,602,517	3,686,388	2,774,526	1,099,836	2,881,736	6,756,098	1,282,908	42,333	14,495
December	1,133,766	340,501	797,442	2,271,709	1,174,860	630,988	1,546,096	3,351,944	2,730,133	1,095,583	3,013,103	6,838,819	1,291,123	43,829	11,900
Grand total	12,088,199	4,382,496	8,445,279	24,915,974	8,114,116	7,497,887	11,087,151	26,699,154	40,036,968	14,217,195	30,769,948	85,024,111	14,264,442	539,322	161,161

Converting metric tons crude oil to barrels:

La Rosa	6.91
Tia Juana	6.63
Lagunillas	6.63
Mene Grande	6.69
Mene-Media-Hb. Pintado	7.50
Tarra-Manueles-Rio de Oro	6.69
La Paz	7.00
Concepcion	7.00
Mene de Acosta	7.20

TABLE 1.—(*Continued*)

	Hombre Pintado	La Paz	Concepcion	Tarra	Los Manueles	Rio de Oro	Cumarebo	Quiriquire	Opocual	Pedernales	Amacuro	Cotorra	Las Palmas	Mene de Acosta	Totals
		V.O.C.	V.O.C.	C.D.C.	C.D.C.	C.D.C.	S.O.V.	S.O.V.	S.O.V.	S.O.V.	S.O.V.	S.O.V.	S.O.V.	T.O.V. Ltd.	
January	104	2,744	36,771	93,948	33,951		213,301	2,126,523			49,206	5,219		[1]	9,406,271
February	1,139	12,607	93,352	243,509	54,510		199,834	2,009,360			43,784	9,879	1,063	[1]	13,081,655
March	964	15,589	96,376	270,845	61,153		205,432	2,152,826			46,316	8,822		[1]	14,997,226
April	1,489	19,257	89,929	264,309	58,511		217,568	2,163,955			72,846	7,650		[1]	14,696,815
May	1,050	14,308	88,858	274,337	62,939		226,747	2,046,156			95,574	23,842		[1]	15,465,496
June	1,048	7,749	83,272	248,661	95,700		215,459	2,160,936			95,602	43,191		[1]	16,210,856
July	1,235	10,892	88,424	233,039	115,175	735	246,087	2,215,017			87,346	35,535		[1]	16,470,191
August	2,865	12,012	86,429	240,700	113,897	1,392	227,053	2,238,362			94,298	50,846		[1]	17,216,905
September	2,675	11,095	83,076	245,396	107,635		208,419	2,187,646			85,655	65,931		[1]	17,426,542
October	2,951	56,896	84,686	233,722	106,210	1,746	203,636	2,246,152			73,851	57,364		[1]	17,732,253
November	11,886	82,607	79,499	237,047	97,293		200,291	2,141,508			82,191	60,211		[1]	17,019,314
December	9,850	95,438	82,054	268,864	98,811		209,885	2,189,503			94,792	64,536		7,335	16,930,392
Grand total	37,256	341,194	992,726	2,854,377	1,005,785	3,873	2,573,712	25,877,944			921,461	433,026	1,063	7,335	186,653,916

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[1] Figures for production of El Mene de Acosta field not available until December, when one total for the period January to mid-September shown. Field closed down mid-September and wells capped.

TABLE 2.—*Production Records by Fields*

Field	1917	1918	1919	1920	1921	1922	1923	1924	1925	1926	1927	1928
Mene Grande	225,783	367,304	258,478	526,119	1,498,052	2,397,602	4,757,152	4,860,482	6,362,151	8,443,418	9,818,296	13,287,716
El Mene								1,079,662	2,637,020	2,316,690	2,475,084	1,866,538
Media												
Hombre Pintado												23,124
Ambrosio									729,317	1,729,317	1,272,323	1,969,327
La Rosa								3,212,134	10,899,278	21,215,300	19,309,649	25,106,656
Punta Benitez										133,684	1,146,278	1,221,971
Tia Juana												
Lagunillas										1,207,913	28,825,578	61,451,468
Concepcion									265,539	832,501	633,782	195
La Paz									286,103	734,280	228,910	6,962
Tarra										49,513	107,188	135,485
Los Manueles												
Rio de Oro												
Cumarebo												
Quiriquire												
Pedernales												
Amacuro												
Cotorra												
Orocual												
Totumo												51,975
Las Palmas												
Urumaco												
Guanoco								112,400	64,495	242,373	317,191	381,607
Netick												
Mene de Acosta												
Total	225,783	367,304	258,478	526,119	1,498,052	2,397,602	4,757,152	9,264,678	21,243,903	36,904,989	64,134,279	105,503,024

TABLE 2.—(*Continued*)

	1929	1930	1931	1932	1933	1934	1935	1936	1937	Total
Mene Grande	15,927,710	20,742,386	11,953,658	13,213,780	13,045,545	15,235,057	15,360,488	15,428,454	14,264,442	187,974,073
El Mene	2,013,234	1,888,263	1,768,930	1,739,437	890,390	751,987	724,695	583,931	539,322	21,277,183
Media					800,410	203,243	105,492	227,456	161,161	1,497,762
Hombre Pintado	39,163	26,935	25,221	23,046	16,192	16,694	17,276	15,248	37,256	240,155
Ambrosio	12,174,698	5,128,862	1,600,540	1,959,088						
La Rosa	27,337,154	23,266,755	19,367,027	21,681,056	24,971,792	23,057,211	21,538,642	21,287,809	24,915,974	317,441,977
Punta Benitez	483,040	234,727	31,596	460,772						
Tia Juana									26,699,154	26,699,154
Lagunillas	78,493,631	75,376,078	65,844,197	61,352,198	58,141,883	72,619,348	81,218,677	85,997,554	85,024,111	755,552,636
Concepcion	25,165	3,180,537	4,637,797	2,153,869	2,153,646	1,742,679	1,416,050	1,111,693	992,726	19,146,179
La Paz	57,181	279,470	662,810	414,253	281,451	241,367	169,736	183,820	341,194	3,887,537
Tarra	180,186	5,114,213	4,450,179	3,329,294	3,347,602	4,414,621	3,925,351	3,412,569	2,854,377	31,320,578
Los Manueles			3,196,800	3,009,744	4,260,085	2,038,387	1,119,336	825,450	1,005,785	15,455,587
Rio de Oro									3,873	3,873
Cumarebo			19,779	2,086,341	4,931,342	3,860,661	3,021,580	2,794,092	2,573,712	19,287,507
Quiriquire	48,784	1,149,905	3,072,010	4,969,254	6,756,702	13,721,766	19,874,565	23,176,855	25,877,944	98,647,785
Pedernales						18,209	27,048	4,076		49,333
Amacuro						17,340		135,439	921,461	1,074,240
Cotorra									433,026	433,026
Orocual								9,951		9,951
Totumo	68,619	10,101	9,093	1,848						141,636
Las Palmas	16,279	28,410	114,353				4,854	10,285	1,063	175,244
Urumaco	88,180	91,707	25,185							205,072
Guanoco	442,317	248,663	46,759							1,855,805
Netick				55,118						55,118
Mene de Acosta	144,000	224,758	197,022	116,384	91,334	46,694		24,290	7,335	851,817
Total	137,541,341	136,991,770	117,022,956	116,565,482	119,688,374	137,985,264	148,523,790	155,228,982	186,653,916	1,503,283,228

TABLE 3.—*Summary of Production Ending Jan.* 1, 1938, *Venezuela*

Fields over 1 Yr. Old	Production, Bbl. of 42 Gal.			Number of Wells Producing by Various Methods			Age of Field, Years	Average Gravity of Oil, A.P.I.
	Prior to 1937	During 1937	Cumulative to Jan. 1, 1938	Flowing	Gas and Air-lift	Pumping		
Ambrosio	292,526,003	24,915,974	317,441,977	181	73	504	14	25.00
La Rosa								
Punta Benitez								
Tia Juana		26,699,154	26,699,154	224		8	1	15.60
Lagunillas	670,528,525	85,024,111	755,552,636	245	81	557	11½	16.70
Mene Grande	173,709,631	14,264,442	187,974,073	53	73	17	24	[2]
El Mene	20,737,861	539,322	21,277,183		41	42	17½	37.20
Media	1,336,601	161,161	1,497,762	2	7		7	37.50
Hombre Pintado	202,899	37,256	240,155			1	9	36.67
La Paz	3,546,343	341,194	3,887,537	3		21	15	21.60
Concepcion	18,153,453	992,726	19,146,179	3		75	13	35.40
Rio de Oro		3,873	3,873				22	30.20
Tarra	28,466,201	2,854,377	31,320,578	8		21	21½	[3]
Los Manueles	14,449,802	1,005,785	15,455,587	8			11	[4]
Guanoco	1,855,805		1,855,805				24	10.49
Mene de Acosta	844,482	7,335	851,817				11	[5]
Totumo	141,636		141,636				22½	20.98
Las Palmas	174,181	1,063	175,244				9	34.00
Cumarebo	16,713,795	2,573,712	19,287,507	33		14	7	[5]
Quiriquire	72,769,841	25,877,944	98,647,785	157		31	9	16.00
Pedernales	49,333		49,333				4	15.00
Orocual	27,291[1]		9,951[1]				4	13.00
Amacuro	135,439	921,461	1,074,240	5			2	18.70
Cotorra		433,026	433,026	3			1	21.50
Urumaco	205,072		205,072				11½	34.00
Netick	55,118		55,118				5	27.00
Total	1,316,629,312	186,653,916	1,503,283,228					

[1] Adjusted, as original figure includes production now included under new fields.

[2] 28° and 17.45°.

[3] 30.2° and 22.6°.

[4] From 41° to 50°.

[5] Production prior to Jan. 1, 1931 included with Tarra.

air or gas lift, these figures for Jan. 1, 1937 being respectively as follows: 1162; 570; 273.

Table 5 is the completion compilation for producing oil wells in Venezuela up to Jan. 1, 1938, and includes two new fields, Tia Juana (L.P.C. and V.O.C.)* and Coturra (S.O.V.). This table shows that

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* Abbreviations of company names used throughout this paper are as follows:

B.C.O., British Controlled Oilfields, Ltd.

V.O.C., Venezuelan Oil Concessions, Ltd.

C.D.C., Colon Development Co., Ltd.

S.O.V., Standard Oil Company of Venezuela.

R.P.V., Richmond Petroleum Company of Venezuela.

C.E.P.S.A., Compañia Espanola de Petroleo.

N.Y.B., New York & Bermudez Co.

T.O.V., Tocuyo Oilfields of Venezuela.

O.O.C., Orinoco Oil Co.

L.P.C., Lago Petroleum Corporation.

C.P.C., Caribbean Petroleum Co.

M.G.O., Mene Grande Oil Co. (formerly Venezuela Gulf Oil Co.).

TABLE 4.—*Producing Fields, Showing Method of Producing as of January* 1, 1938, *Venezuela*

Fields	Lago				Gulf				V.O.C.				C.P.C.				C.D.C.				B.C.O. Ltd.				S.O.V.				T.O.V. Ltd.				Summary			
	A	*B*	*C*	*D*	*A*	*B*	*C*	*D*	*A*	*B*	*C*	*D*	*A*	*B*	*C*	*D*	*A*	*B*	*C*	*D*	*A*	*B*	*C*	*D*	*A*	*B*	*C*	*D*	*A*	*B*	*C*	*D*	*A*	*B*	*C*	*D*
La Rosa	250	115	9	126	188	25		163	320	41	64	215																					758	181	73	504
Tia Juana	51	51			68	66		2	113	107		6																					232	224		8
Lagunillas	349	112	71	166	213	17		196	321	116	10	195																					883	245	81	557
Concepcion									78	3		75																					78	3		75
La Paz									24	3		21																					24	3		21
Mene Grande													143	53	73	17																	143	53	73	17
Tarra																	29	8		21													29	8		21
Los Manueles																	8	8															8	8		
El Mene																					83		41	42									83		41	42
Media																					9	2	7										9	2	7	
Hombre Pintado																					1			1									1			1
Cumarebo																									47	33		14					47	33		14
Quiriquire																									188	157		31					188	157		31
Pedernales																																				
Orocual																																				
Amacuro																									5	5							5	5		
Cotorra																									3	3							3	3		
Las Palmas																																				
Mene de Acosta																																				
Totals	650	278	80	292	469	108		361	856	270	74	512	143	53	73	17	37	16		21	93	2	48	43	243	198		45					2491	925	275	1291

A, Number of wells.
B, Flowing.
C, Gas and air-lift.
D, Pumping.

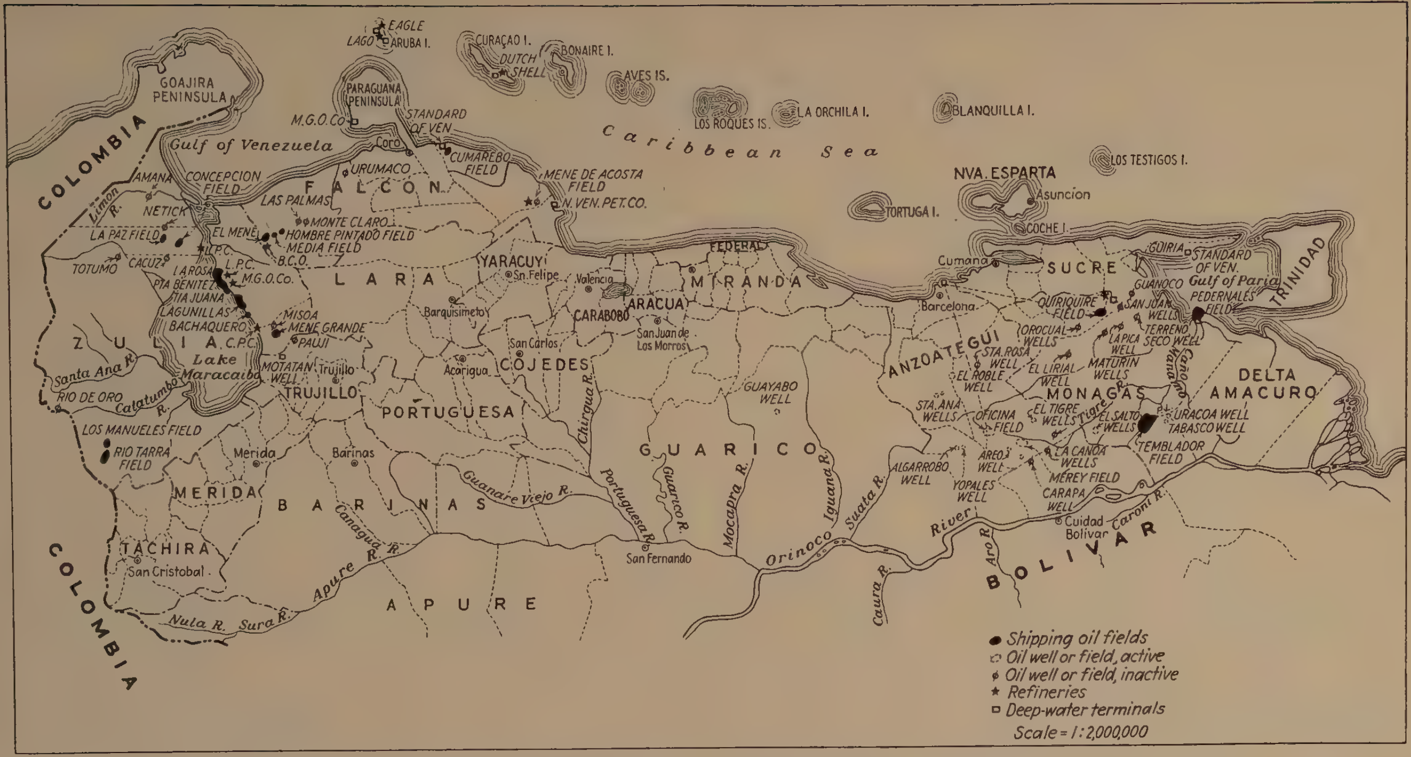

FIG. 1.—OIL FIELDS, TERMINALS AND REFINERIES IN VENEZUELA.

TABLE 5.—*Completion Compilation for Producing Fields in Venezuela, January 1, 1938*

Year	Ambrosio Field			La Rosa Field			Punta Benitez Field			Tia Juana Field			Lagunillas Field			Mene Grande	El Mene	Media	Hb. Pintado
	Lago	V.G.O.	V.O.C.	Lago	V.G.O	V.O.C.	Lago	V.G.O.	V.O.C.	Lago	V.G.O.	V.O.C.	Lago	V.G.O.	V.O.C.	C.P.C.	B.C.O.	B.C.O.	B.C.O.
1914																2			
1915																3			
1916						1										1			
1917																			
1918						2													
1919																1			
1920																	1		
1921																3	6		
1922						1										1	2		
1923																10	16		
1924				4	2	7										17	23		
1925	1	1		26	20	22										22	43		
1926	10	10	2	27	30	77	1	3					2	2	3	35	51		
1927	21	7		28	20	45	25	8	1				33	24	18	52	46		
1928	4	10		46	22	36	5	1					73	51	76	20	49	2	
1929	10	21		4	55	170	1						75	100	48	32	23	3	2
1930		18		1	39	85		2					22	36	53	36	20	2	3
1931						28								5	1	6	4	3	
1932						10									2		1	2	
1933				5	2	27							3		28			10	
1934				16			14						65		50	11		3	
1935				21	1		20						23		23	32			
1936				25	2	2	15			1		14	82	13	66	22		2	
1937				6	9	19	32			69	64	108	18	17	70[1]	17		3	1
Totals.........	46	67	2	209	202	532	113	14	1	70	64	122	396	248	438	323	285	30	6

[1] Includes three Bachaquero wells.

TABLE 5.—(*Continued*)

Year	La Paz	Concepcion	Tarra and Manueles	Oro	Totumo	Las Palmas	Cumarebo	Quiriquire	Pedernales	Orocual	Amacuro	Cotorra	Urumaco	Guanoco	Mene de Acosta	Totals
	V.O.C.	V.O.C.	C.D.C.	CD.C.	S.O.V.	S.O.V.	S.O.V.	S.O.V.	S.O.V.	S.O.V.	S.O.V.	S.O.V.	R.P. Co. V.	N.Y. & B. Co.	T.O.V. Ltd.	
1914														7		9
1915				2	1									2		8
1916			1											1		4
1917			1													1
1918			1													3
1919			2													3
1920																1
1921	2															11
1922	1		1													6
1923																26
1924	1		1												1	56
1925	6	18	2											2	1	164
1926	14	28	6											2	2	305
1927	4	19	9	2										3	6	371
1928			7		1	3		2					1	3	5	417
1929			15		10	2		8					2	2	12	595
1930	5	16	31			6		23					2	2	26	428
1931	2	19	7			2	5	14					1		17	114
1932			3				14	6							8	46
1933		2	4				24	14							2	121
1934			4				26	37	1	4						231
1935							13	39	1						1	174
1936							8	36			2					290
1937			3				12	58			2	4				512
Totals............	35	102	98	4	12	13	102	237	2	4	4	4	6	24	81	3896

3698 wells were completed in Venezuela between 1914 and Jan. 1, 1938, the year 1937 being the second highest year on record, with 512 completions, the previous peak having been in 1929, when 595 wells were completed. From the present plans it appears that a new record will be made in 1938. Of the 512 wells completed in 1937, Dutch Shell completed 217; L.P.C., 125; M.G.O., 90; S.O.V. 76 and B.C.O., 4. No wells were completed during 1937 in Ambrosio, El Mene, La Paz, Concepcion, Rio De Oro, Totumo, Las Palmas, Pedernales, Orocual, Urumaco, Guanoco, El Mene de Acosta and Netick. Plans call for extensive drilling operation due south from Lagunillas in 1938, in the Bachaquero and Pueblo Viejo areas as well as in eastern Venezuela. Table 6 shows the summary

TABLE 6.—*Summary of Drilling Operations Ending Jan. 1, 1938, Venezuela*

Fields	Area Proven, Acreage[2]	Oil Wells Drilled				Abandoned Producers	Total	Average Depth of Hole Drilled to Date, Ft.	Active Drilling Operations End Jan. 1, 1938		
		Prior to Jan. 1, 1937		During 1937							
		Producers	Dry or Junked	Producers	Dry or Junked				Oil	Exploratory or Wildcat	Gas
Ambrosio	28,070	1,078	21	66		69	1,165	2,360	1		
La Rosa											
Punta Benitez											
Tia Juana	7,210	986	10	241		21	1,343	2,475	9		
Lagunillas[1]	40,865			105	1			3,100 and 3,780	7	3	
Mene Grande	5,980	290	16	17		14	323	3,750	5		
El Mene	850	227	58			121	285	1,000	1		
Media	55	18	13	3	3	13	37	3,500			
Hombre Pintado	150	4	1	1			6	1,600	3		
La Paz	255	31	4			2	35	1,310			
Concepcion	910	101	1			1	102	1,718			1[4]
Rio Tarra	985	67	13	2		10	82	2,310	2[5]		
Rio de Oro	400	2	2				4	1,630			
Los Manueles	255	13	2	1		2	16	4,020	1		
Guanoco	150	15	9			10	24	1,300			
Mene de Acosta	75	40	41			67	81				
Totumo	300	10	2			2	12	2,360			
Las Palmas	50	7	6			5	13	2,750			
Cumarebo	470	78	13	12[3]		15	103	1,625	1		
Quiriquire	10,250	169	11	58		13	238	3,000	3	1	
Urumaco	100	4	2			3	6	3,385			
Netick		2					2				
Pedernales	130	4	4	6		2	14	5,830		1	
Orocual	975	1	3			4	4	3,000			
Total	98,485	3,147	232	512	4	374	3,895		33	5	1

[1] Includes Bachaquero: 4750.

[2] As at Jan. 1, 1937.

[3] Also one gas well drilled.

[4] Sibucara.

[5] Includes one deepening job.

of drilling operations for the year 1937 and as of Jan. 1, 1938, by fields in all detail. It should be noted from this table that the new field of Tia Juana was the most active and 241 wells were completed in that field during 1937. Table 6 also shows the proven area of all the oil fields, which now reaches 98,485 acres. In connection with the average depths, Table 6 shows two figures for Lagunillas field, the first representing the average for the north part of the field and the second for the south part, wells drilled in the north part being much shallower than in the south half. This table also shows that at the end of the year 33 strings of tools were at work in the proven oil fields; five strings in exploration work and one in drilling a gas well.

EXPORTS

Shipments of crude oil from all Venezuelan fields reached another record total of 171,217,920 bbl., exceeding the preceding record set in 1936 by some 22,000,000 bbl. Analyzing the year's total exports by months, the highest exports occurred in September, when 16,429,986 bbl. were exported, while the smallest export month was January 1937, with a total of but 8,279,995 bbl. The latter, however, was caused principally by the oil-field strike in which some of the tanker fleets joined through sympathy with the oil-field workers. Table 7 shows the exports from Venezuela by fields, by companies and by months, indicating that Lagunillas field is the leading source of exports, having contributed 47.5 per cent of exports during 1937, as compared with 57 per cent in the preceding year, this decline being due to the prolific production developed in the new Tia Juana field. This latter contributed 14.5 per cent of the total in 1937. The total accumulated crude-oil exports from Venezuela, for the period 1917 to 1937 inclusive, amounted to 1,407,719,981 bbl., as shown on Table 8, which further breaks the exports by years, by fields, from the inception of production in each field.

LAKE TRANSPORTATION IN VENEZUELA

Table 9 shows the capacity of the tanker fleets operating in the Maracaibo Lake Basin district by the three companies interested: the Royal Dutch Shell group; the Lago Petroleum Corporation and the Mene Grande Oil Co., C.A. (Gulf). This table gives the name of each tanker, its capacity, based on crude cargos at draft 12 ft. 6 in., average trips per month and the carrying capacity by month and for the entire year, the latter figures being based upon the average number of trips that can be made by each vessel under normal conditions. The total annual carrying capacity of the three fleets, 176,909,800 bbl., is an increase of 13,000,000 bbl. over the 1936 capacity, there having been a number of new tankers added in 1937. As compared with the total carrying capacity,

TABLE 7.—*Crude Oil Exports, Venezuela, 1937*

	La Rosa Field						Tia Juana Field				Lagunillas Field					
	Lago	Gulf	V.O.C.	S.O.V.	Cia. Esp. Pet.	Total	Lago	Gulf	V.O.C.	Total	Lago	Gulf	V.O.C.	S.O.V.	Cia. Esp. Pet.	Total
January	696,826	34,088	100,636	17,547	17,681	866,778	39,645			39,645	2,345,163	328,747	1,280,255	233,957		4,188,122
February	652,820	388,896	728,587	50,520		1,820,823	53,224			53,224	2,464,155	1,014,417	2,616,803	453,393	48,878	6,597,646
March	999,989	359,956	784,096	64,486		2,208,527	71,099		44,341	115,440	3,157,033	890,789	3,009,392	397,377	51,129	7,505,720
April	897,061	280,035	568,433	42,393	17,403	1,805,325	70,882	78,729	265,486	415,097	3,766,866	708,508	2,781,236	344,243	35,060	7,635,913
May	816,772	276,065	643,389	73,549		1,809,775	230,735	480,293	511,868	1,222,896	4,100,809	866,673	2,795,794	437,318	37,557	8,238,151
June	555,817	293,854	543,788	71,680		1,465,139	576,117	987,437	822,359	2,385,913	3,533,198	838,189	2,537,044	373,635	17,594	7,299,660
July	473,513	269,799	793,222	56,873		1,593,407	777,802	1,110,043	1,206,412	3,094,257	3,824,664	745,337	1,928,994	378,781		6,877,776
August	895,090	433,381	752,917	56,468		2,137,856	1,046,249	796,166	1,470,913	3,313,328	3,637,771	682,177	2,046,172	376,531		6,742,651
September	621,312	310,013	771,748	82,928		1,786,001	1,335,720	982,772	1,551,363	3,869,855	3,037,433	974,160	2,305,641	399,092		6,716,326
October	975,892	146,803	768,122	66,055		1,956,872	1,425,525	857,931	1,714,758	3,998,214	2,957,858	280,455	2,823,325	461,292		6,522,930
November	940,816	148,699	721,185	47,590		1,858,290	1,312,258	474,605	1,485,037	3,271,900	2,893,794	772,339	2,686,128	328,773		6,681,034
December	605,084	215,719	728,394	56,121		1,605,318	1,174,860	578,363	1,398,942	3,152,165	2,546,024	576,864	2,887,966	359,454		6,370,308
Grand total	9,130,992	3,157,308	7,904,517	686,210	35,084	20,914,111	8,114,116	6,346,339	10,471,479	24,931,934	38,264,768	8,678,655	29,698,750	4,543,846	190,218	81,376,237

Converting metric tons crude oil to barrels:

La Rosa	5.91
Lagunillas	6.63
Tia Juana	6.63
Mene Grande	6.69
Mene + Media	7.50
La Paz	7.00
Concepcion	7.43
Tarra + Manueles	7.20
Mene de Acosta	7.20

TABLE 7.—(*Continued*)

	Mene Grande	El Mene[1]	La Paz	Concepcion	Mene de Acosta	Tarra-Manueles	Cumarebo	Quiriquire	Pedernales	Totals
	C.P.C.	B.C.O.	V.O.C.	V.O.C.	T.O.V. Ltd.	C.D.C.	S.O.V.	S.O.V.	S.O.V.	
January	861,853	37,262				109,340	254,336	1,869,518	46,141	8,272,995
February	655,526	75,538		92,929		378,154	120,120	1,682,890	43,535	11,520,385
March	643,226	57,457	18,060	132,132		366,120	321,003	2,112,177	46,050	13,525,912
April	650,301	73,976	14,408	90,237		350,234	144,527	1,930,526	52,405	13,162,949
May	816,053	56,537		50,594		366,916	219,499	2,174,641	75,869	15,030,931
June	828,481	39,280		154,173		323,866	312,013	1,996,757	154,310	14,959,592
July	986,577	57,510		54,409		369,367	208,933	2,208,077	144,345	15,594,658
August	955,080	59,472		132,471		353,953	182,177	1,980,394	24,585	15,881,967
September	1,008,063	59,635		99,201		391,123	260,112	2,041,730	197,940	16,429,986
October	944,951	44,571	34,943	41,022		389,067	118,484	1,587,328	196,061	15,834,443
November	831,085	60,038	84,809	66,277		391,538	186,195	2,104,625	79,331	15,615,122
December	961,750	58,927	103,801	120,895		425,591	224,698	2,270,552	94,975	15,388,980
Grand total	10,142,946	680,203	256,021	1,034,340	[2]	4,215,269	2,552,097	23,959,215	1,155,547	171,217,920

[1] Includes Media and Hombre Pintado crude.

[2] No exports in 1937.

TABLE 8.—*Exports Record, Venezuela, by Fields*

Field	1917	1918	1919	1920	1921	1922	1923	1924	1925	1926	1927	1928
Mene Grande	57,096	143,880	14,309		997,643	1,813,452	3,344,428	4,575,484	5,916,035	8,260,779	7,909,387	9,680,536
El Mene-Media								1,066,837	2,620,738	2,155,599	2,476,915	1,812,187
La Rosa								2,911,229	9,852,485	20,797,670	17,512,380	27,597,505
Tia Juana												
Lagunillas										797,590	26,895,232	58,445,581
Concepcion									283,609	1,422,040	633,782	
La Paz									204,515		177,835	
Guanoco									41,000		321,576	364,332
Mene de Acosta												
Tarra-Manueles												
Quiriquire												
Cumarebo												
Guiria												
Pedernales												
Totals	57,096	143,880	14,309		997,643	1,813,452	3,344,428	8,553,550	18,918,382	33,433,678	55,927,107	97,900,141

Field	1929	1930	1931	1932	1933	1934	1935	1936	1937	Total
Mene Grande	12,576,072	16,893,334	8,640,390	9,516,560	8,255,387	10,629,253	11,019,091	12,135,742	10,142,946	142,521,804
El Mene-Media	2,004,188	1,856,940	1,754,514	1,774,819	1,617,376	990,722	792,184	823,539	680,203	22,426,761
La Rosa	40,079,776	27,908,008	19,947,114	22,954,444	24,214,674	21,555,357	20,397,009	21,056,103	20,914,111	297,697,865
Tia Juana									24,931,934	24,931,934
Lagunillas	72,431,744	77,347,534	67,451,418	60,949,932	58,882.944	70,984,747	80,888,359	84,990,558	81,376,237	741,441,876
Concepcion	25,152	3,197,019	4,599,713	2,090,215	2,069,926	1,708,770	1,377,457	1,146,171	1,034,340	19,588,194
La Paz	30,000	256,757	605,406	398,773	268,697	223,552	172,737	174,719	256,021	2,769,012
Guanoco	360,000	224,280	87,604							1,398,792
Mene de Acosta		171,948	137,689	89,081	99,896	11,311				509,925
Tarra-Manueles		4,984,719	7,350,873	6,112,010	6,972,697	5,229,387	4,983,995	4,521,934	4,215,269	44,370,884
Quiriquire		888,713	2,950,539	4,519,373	5,826,927	12,500,730	17,112,771	11,467,784	23,959,215	79,226,052
Cumarebo				1,970,443	4,874,343	3,793,412	3,058,775	2,770,409	2,552,097	19,019,479
Guiria							607,862	10,054,004	[1]	10,661,866
Pedernales									1,155,547	1,155,547
Totals	127,506,932	133,729,252	113,525,260	110.375,640	113,082,867	127,627,241	140,410,240	149,140,963	171,217,920	1,407,719,981

[1] Actually Quiriquire and Pedernales oil are included this year under their respective headings.

143,551,061 bbl. were actually moved from Lake Maracaibo during 1937 while 124,848,766 bbl. were transported in 1936.

The Dutch Shell group increased its Lake Maracaibo fleet by three tankers during 1937, and plans provide that four new tankers will be added to this fleet in 1938. The Lago Petroleum Corporation increased

TABLE 9.—*Lake Transportation, Venezuela, January* 1, 1938

No.	Name of Tanker	Capacity, Bbl.	Trips	Amount Carried, Bbl.	
				Monthly	Yearly
	DUTCH SHELL GROUP				
1	Adela	18,500	10	185,000	2,220,000
2	Alicia	18,500	10	185,000	2,220,000
3	Berta	18,500	10	185,000	2,220,000
4	Brigida	18,500	10	185,000	2,220,000
5	Carlota	18,500	10	185,000	2,220,000
6	Casandra	18,500	10	185,000	2,220,000
7	Chepita	18,500	10	185,000	2,220,000
8	Conchita	18,500	10	185,000	2,220,000
9	Elena	18,500	10	185,000	2,220,000
10	Frasca	18,500	10	185,000	2,220,000
11	Felipa	18,500	10	185,000	2,220,000
12	Julieta	18,500	10	185,000	2,220,000
13	Juliana	18,500	10	185,000	2,220,000
14	Justina	18,500	10	185,000	2,220,000
15	Leticia	18,500	10	185,000	2,220,000
16	Liseta	18,500	10	185,000	2,220,000
17	Lucita	18,500	10	185,000	2,220,000
18	Lucrecia	18,500	10	185,000	2,220,000
19	Manuela	18,500	10	185,000	2,220,000
20	Mariana	18,500	10	185,000	2,220,000
21	Marsella	18,500	10	185,000	2,220,000
22	Martica	18,500	10	185,000	2,220,000
23	Martina	18,500	10	185,000	2,220,000
24	Maruja	18,500	10	185,000	2,220,000
25	Matilde	18,500	10	185,000	2,220,000
26	Maximina	18,500	10	185,000	2,220,000
27	Susana	18,500	10	185,000	2,220,000
28	Juanita	14,500	10	145,000	1,740,000
29	Rosa	24,000	10	240,000	2,880,000
30	Rita	24,000	10	240,000	2,880,000
31	Ramona	24,000	10	240,000	2,880,000
32	Renata	24,000	10	240,000	2,880,000
33	Rosaura	24,000	10	240,000	2,880,000
34	Rufina	24,000	10	240,000	2,880,000
35	Rodas	24,000	10	240,000	2,880,000
	Total	682,000	350	6,820,000	81,840,000
	AREND PETROLEUM MAATSCHAPPIJ				
36	San Casto	18,500	11	203,500	2,442,000
37	San Claudio	18,500	11	203,500	2,442,000
	Total	37,000	22	407,000	2,884,000

its fleet by three tankers during 1937 and five additional tankers will be added in 1938. Mene Grande Oil Co. made no additions to its fleet in 1937, and sold one tanker to the Lago Petroleum Corporation.

TABLE 9.—(*Continued*)

No.	Name of Tanker	Capacity, Bbl.	Trips	Amount Carried, Bbl.	
				Monthly	Yearly
	LAGO PETROLEUM CORPORATION				
1	Ambrosio	16,700	11	183,700	2,204,400
2	Andino	24,000	11	264,000	3,168,000
3	Hooiberg	18,000	11	198,000	2,376,000
4	Icotea	16,700	11	183,700	2,204,400
5	Invercaibo	16,700	11	183,700	2,204,400
6	Inverlago	16,700	11	183,700	2,204,400
7	Inverrosa	16,700	11	183,700	2,204,400
8	Inverruba	16,700	11	183,700	2,204,400
9	Lagunilla	16,700	11	183,700	2,204,400
10	La Salina	16,700	11	183,700	2,204,400
11	Maracay	24,500	11	269,500	3,234,000
12	Oranjestad	16,700	11	183,700	2,204,400
13	Sabaneta	16,700	11	183,700	2,204,400
14	San Carlos	16,700	11	183,700	2,204,400
15	San Nicolas	16,700	11	183,700	2,204,400
16	Punta Gorda	18,000	11	198,000	2,376,000
17	Surinam	21,000	11	231,000	2,772,000
18	Tamare	21,500	11	236,500	2,838,000
19	Tia Juana	18,000	11	198,000	2,376,000
20	Ule	21,500	11	236,500	2,838,000
21	Yamanota	18,000	11	198,000	2,376,000
22	Cumarebo	18,000	11	198,000	2,376,000
23	Bachaquero	24,500	11	269,500	3,234,000
24	Paraguana	14,500	11	159,500	1,914,000
25	Misoa	24,500	11	269,500	3,234,000
	Total	466,000	275	5,130,400	61,564,800
	MENE GRANDE OIL COMPANY C.A.				
1	Catatumbo	21,000	11	231,000	2,772,000
2	Caroni	21,000	11	231,000	2,772,000
3	Apure	21,000	11	231,000	2,772,000
4	Acosta	17,500	11	192,500	2,310,000
5	Aragua	17,500	11	192,500	2,310,000
6	Bolivar	17,500	11	192,500	2,310,000
7	Monagas	17,500	11	192,500	2,310,000
8	Paez	17,500	11	192,500	2,310,000
9	Perija	17,500	11	192,500	2,310,000
10	Sucre	17,500	11	192,500	2,310,000
11	Urdaneta	17,500	11	192,500	2,310,000
12	Toas	14,500	11	159,500	1,914,000
13	Zapara	14,500	11	159,500	1,914,000
	Total	232,000	143	2,552,000	30,624,000
	Grand total				176,909,800

TABLE 10.—*Venezuela Tank Storage*[1]

Companies	Location	Capacity, 1000 Bbl.																								
		94.5	92.0	85.0	80.0	75.0	67.5	67.0	64.0	63.0	55.0	35.0	25.0	23.0	22.0	21.4	20.0	19.0	15.6	15.0	13.0	10.0	7.5	6.25	6.6	5.0
British Controlled Oilfields, Ltd.	El Mene-Media										2	1														2
	Hombre Pintado																									
	La Estacada										1	2										2				
Caribbean Petroleum Co.	Mene Grande						4		1		3		4				4									
	San Lorenzo						5		2		6															
Colon Development Co. Ltd.	Casigua						1			4							2					2				
	Escalante													1		4										
	Calvario													1										1		
	Rivera													1											1	
Standard Oil Co. of Ven.	Las Palmas																									
	Totumo										1															
	Cumarebo																									
	Tucupido				2						1						1									
	Quiriquire																									2
	Temblador																									
	Pedernales																									5
	Guiria				9																					
	Caripito	3[2]			4																					
Lago Petroleum Corp.	La Salina				2[4]	2					6															
	Pta. Gorda				8	1																				
	Rio Ule				8																					
	Lagunillas				23	2																				
Mene Grande Oil Co. C.A. (Gulf)	Ambrosio										4															
	Cabimas										13															
	Pta. Benitez										14		3													
	Tasajeras										10															
	Lagunillas										5											1				
	Tia Juana[3]										2[9]															
	Paraguaná				37																					

[9] Torn down from Ambrosio in 1936 and erected here during 1937.

TABLE 10.—(*Continued*)

Companies	Location	Capacity, 1000 Bbl.																								
		94.5	92.0	85.0	80.0	75.0	67.5	67.0	64.0	63.0	55.0	35.0	25.0	23.0	22.0	21.4	20.0	19.0	15.6	15.0	13.0	10.0	7.5	6.25	6.6	5.0
New York & Bermudes Co.	Guanoco										2															1
Tocuyo Oilfields, Ltd.	El Mene											2								1						
Venezuelan Oil Concs. Ltd.	La Paz																		1		1					
	Concepcion						1												1							
	Punta Piedras			1													2									
	Cabimas			2			3	2																		
	La Rosa			1							2															
	Tia Juana	1								1	1															
	Lagunillas				2		4		3									12								
Compañia Petroleo de Lago	La Arriaga																5									
Coro Petroleum Co.	Urumaco																									4
Orinoco Oil Co	Netick																									
Totals		4		4	95	5	18	2	6	5	73	5	7	3		4	14	12	2	1	1	5		1	1	14

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[1] Total number of tanks, 404.

[2] Actually 95,000-bbl. tanks, put up during 1937.

[3] Actually called "Taparito" by Gulf.

[4] One of these moved in from Punta Gorda during 1937.

TABLE 10.—(*Continued*)

Companies	Location	Capacity, 1000 Bbl.											Total Capacity		Crude in Storage		Available Capacity	
		3.3	2.5	1.8	1.5	1.3	1.25	1.0	0.5	0.25	0.14	0.10	At Location	Grand Total	At Location	Grand Total	At Location	Grand Total
British Controlled Oilfields, Ltd.	El Mene-Media				1				3				158,000		16,511		141,489	
	Hombre Pintado				4								6,000		1,041		4,959	
	La Estacada												145,000	309,000	4,485	22,037	140,515	286,963
Caribbean Petroleum Co.	Mene Grande												679,000		352,869		326 131	
	San Lorenzo												795,500	1,474,500	383,690	736,559	411,810	737,941
Colon Development Co. Ltd.	Casigua												379,500		109,050		437,900	
	Escalante												108,600					
	Calavario												29,250					
	Rivera												29,600	546,950		109,050		437,900
Standard Oil Co. of Ven.	Las Palmas				5			2					9,500				9,500	
	Totumo												55,000				55,000	
	Cumarebo							10					10,000		151,100		3,900	
	Tucupido												235,000					
	Quiriquire				27				32	20			71,500		37,171		34,329	
	Temblador																	
	Pedernales							8					33,000[6]		11,724		21,276	
	Guiria												720,000		409,754		310,246	
	Caripito												605,000	1,739,000	311,631	921,380	293,369	817,620
Lago Petroleum Corp.	La Salina												640,000		420,064		219,936	
	Pta. Gorda												715,000		633,905		81,095	
	Rio Ule												640,000		538,450		101,550	
	Lagunillas												1,990,000	3,985,000	1,552,507	3,144,926	437,493	880,074
Mene Grande Oil Co. C. A. (Gulf)	Ambrosio												220,000		211,944		8,056	
	Cabimas												715,000		559,078[7]		155,922	
	Pta. Benitez												845,000		768,169		76,831	
	Tasajeras												550,000		693,174[8]		141,826	
	Lagunillas												285,000					
	Tia Juana[3]												110,000		14,730		95,270	
	Paraguana												2,960,000	5,685,000	2,370,878[10]	4,617,973	589,122	1,067,027

TABLE 10.—(*Continued*)

Companies	Location	Capacity, 1000 Bbl.											Total Capacity		Crude in Storage		Available Capacity	
		3.3	2.5	1.8	1.5	1.3	1.25	1.0	0.5	0.25	0.14	0.10	At Location	Grand Total	At Location	Grand Total	At Location	Grand Total
New York & Bermudes Co.	Guanoco												115,000	115,000	10,000	10,000	105,000	105,000
Tocuyo Oilfields, Ltd.	El Mene		1										87,500	87,500	8,000	8,000	79,500	79,500
Venezuelan Oil Concs. Lts.	La Pas												28,600		17,052		11,548	
	Concepcion												83,100		53,704		29,396	
	Punta Piedras												125,000		61,913[11]		63,087	
	Cabimas												506,500		379,287		322,213	
	La Rosa												195,000					
	Tia Juana												212,500		153,476		59,024	
	Lagunillas					3							853,900	2,004,600	434,010	1,099,442	419,890	905,158
Compañia Petroleo de Lago	La Arriaga												100,000	100,000	5,400	5,400	94,600	94,600
Coro Petroleum Co.	Urumaco								1				20,500	20,500	4,700	4,700	15,800	15,800
Orinoco Oil Co.	Netick				2			1		2			4,500	4,500	2,986	2,986	1,514	1,514
Totals			1		39	3		21	36	22			16,071,550	16,071,550	10,682,453	10,682,453	5,389,097	5,389,097

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[5] Two 80,000 and one 5000-bbl. tanks under construction at Boca de Uracos.

[6] Two 82,000 and one 20,000-bbl. tanks under construction at La Brea Terminal.

[7] Includes 21,579 bbl. of S.O.V. oil.

[8] Includes 48,514 bbl. of S.O.V. oil.

[10] Includes 69,176 bbl. S.O.V. (L.P.C. owes Gulf 495,135 bbl.)

[11] Comprises 49,924 bbl. Concepcion and 11,989 bbl. La Paz crude.

TANK STORAGE

Table 10 shows the storage-tank facilities available in Venezuela by companies, the grand total being 16,071,550 bbl. in 404 tanks, and also gives the amount of crude oil in storage as of Jan. 1, 1938, which amounted to 10,682,453 bbl. During 1937 approximately 600,000 bbl. of additional storage capacity was erected.

FIELD DEVELOPMENTS

As a result of 1937 developments, two new fields were added in Venezuela, the Tia Juana in Lake Maracaibo district and the Coturra in northeastern Venezuela. The following brief summary gives the developments in all Venezuela fields during 1937:

Producing Oil Fields

The active producing fields were as follows, reading from west to east:

1. *La Concepcion* (Shell), in the District of Maracaibo, State of Zulia. No drilling is being done at present. Production in 1937 was 992,726 barrels.

2. *La Paz* (Shell), 30 km. northwest of Concepcion. No drilling was done in 1937. Production was 341,194 barrels.

3. *Tarra* (Shell), in the District of Colon, State of Zulia. Two strings are in operation. Production in 1937 was 2,854,377 barrels.

4. *Los Manueles* (Shell), 25 km. north of the Tarra field. One string is in operation. Production in 1937 was 1,005,785 barrels.

5. *Ambrosio, La Rosa and Punta Benitez* (known as the La Rosa area), on the eastern side of Lake Maracaibo, in the District of Bolivar, State of Zulia, are operated by the three major companies, Shell (all concessions on the land), Gulf, operating a kilometer strip running alongside the coast in the Lake;* and Lago, owning and operating all other concessions in the Lake. Offset drilling was carried out throughout 1937 by these three companies. Total production in 1937 was 24,915,974 bbl., of which Shell produced 8,445,279, Lago produced 12,088,199 and Gulf, 4,382,496 barrels.

6. *Tia Juana*, a new field, south of Punta Benitez and north of Lagunillas. The same ownership conditions exist here as in the La Rosa area. Development of this field was started early in 1937 and during the year the three companies had an average of five strings each actively engaged in an offset drilling campaign. Production in 1937 was 26,699,154 bbl. (all new production), of which Shell produced 11,087,151 bbl., Lago 8,114,116 and Gulf, 7,497,887 barrels.

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* Most of the parcels in the kilometer strip referred to are Creole parcels operated by the Gulf (operating under the name of the Mene Grande Oil Company, C.A.), the Creole (now Standard Oil Company of Venezuela) receiving royalty oil from these parcels.

7. *Lagunillas*, south of Tia Juana field and probably an extension. The same ownership conditions existing as in the La Rosa and Tia Juana areas. Offset drilling by all three companies was carried out in 1937. Production in 1937 was 85,024,111 bbl., of which Shell produced 30,769,948 bbl., Lago produced 40,036,968 and Gulf, 14,217,195. It is interesting to note that the Lagunillas field was responsible for almost half of the entire production of Venezuela in 1937, the latter figure being 186,646,581 barrels.

8. *Bachaquero*, some 20 km. south of the Lagunillas field, is a new field, where the Shell put on one string in July and is now drilling its sixth well and the Lago put on one string late in December. The Gulf has not, as yet, indicated whether it will commence drilling in this area. This field is not yet on a producing basis.

9. *Mene Grande* (Shell), 17 km. inland from the lake shore, due east of the San Lorenzo refinery of the same company. This field is owned and operated by the Caribbean Petroleum Co. (Shell), no offset situation existing. A seven-string program is in operation in this field, five strings engaged in new drilling and two on workover and repair jobs. Production for 1937 was 14,264,442 barrels.

10. *El Mene* (BritishControlled Oilfields, Ltd.), 54 km. inland due east of Altagracia, in the District of Buchivacoa, State of Falcon, where a deep test is now drilling, prior to which drilling operations were suspended indefinitely several years ago. Production in 1937 was 539,322 barrels.

11. *Media* (B.C.O.), 12 km. north and slightly east of the El Mene field. Owned and operated by the B.C.O Two strings were in operation during the first nine months of 1937, after which they were transferred to the Hombre Pintado field. Production in 1937 was 161,161 barrels.

12. *Hombre Pintado* (Central Area Exploration (Venezuela) Ltd.), operated by the British Controlled Oilfields, Ltd. About 18 km. northeast of the El Mene field. Drilling operations in this field were suspended indefinitely in 1930 but in July 1937 one string was transferred from the Media field and a second one moved in toward the end of the year. New wells completed by the end of 1937 were closed in, awaiting transportation facilities. Production for 1937 was 37,256 barrels.

13. *Cumarebo* (Standard Oil Co. of Venezuela), in the District of Zamora, State of Falcon, owned and operated by the Standard Oil Company of Venezuela, the North Venezuelan Petroleum Co., Ltd. having a working interest and sharing production on a basis of 26.875 per cent royalty, chiefly in oil. One string has been operating in this field during the past year. Production for 1937 was 2,573,712 barrels.

14. *El Mene de Acosta* (Tocuyo Oilfields of Venezuela, Ltd.), in the District of Acosta, State of Falcon, the field being operated by the Tocuyo and owner being North Venezuela Petroleum Co., Ltd. Drilling was

suspended a number of years ago. This field was closed in as a producing field in September 1937, the production equipment being withdrawn and the wells capped. Up to this time, the field was producing only 800 bbl. monthly from six pumping wells. Production for 1937 was 7335 barrels.

15. *Quiriquire* (Standard Oil Company of Venezuela), in the District of Piar, State of Monagas, Eastern Venezuela, owned and operated by the S.O.V. An average of five drilling strings was in operation during 1937; at the end of the year there were three strings actually in operation. The practice of drilling "twin wells," i.e., skidding the rig over from one well and drilling a hole alongside, producing it from either the upper or lower sand, depending from which sand the original hole is producing, was continued in 1937, a total of 24 sets of "twin wells" having been drilled to Dec. 31, 1937. A few individual wells for which no twin wells have been drilled were also completed during the year. Production for 1937 was 25,877,944 barrels.

16. *Pedernales*, in the District of Pedernales, Delta Amacuro, operated by the Standard Oil Company of Venezuela and in which the Venezuelan Seaboard has some interest, was named after the first few wells drilled there but later additional wells were given different names; i.e., "Amacuro" and "Cotorra," for bookkeeping purposes, in connection with royalties. The "Amacuro" wells have averaged 400 to 500 bbl. daily initial production while the "Cotorra" wells have been completed for as much as 2000 bbl. daily initial production. Production for 1937 was 1,354,487 barrels.

Inactive Fields and Wells

1. *Amana* (Gulf), in the District of Mara, State of Zulia, where drilling was suspended many years ago. It is reported to have a closed-in production of 400 bbl. daily but, since no production facilities are available, the field is classified as inactive.

2. *Netick* (Orinoco Oil Co., subsidiary of the Pure Oil Co.), in the District of Mara, State of Zulia, where three wells were drilled, the last of which (Netick No. 2) made 500 bbl. daily, but as there is no outlet for the oil the field has been closed in since 1932, no further drilling having been done.

3. *Totumo* (Standard Oil Company of Venezuela), on the western side of Lake Maracaibo, in the District of Perija, State of Zulia. The field was discovered originally by the Caribbean Petroleum Co. in 1915, when the discovery well was drilled and later turned over to the S.O.V. (then Creole). Before operations were suspended indefinitely, 12 wells were drilled. Production up to December 1931 averaged 26,000 bbl. annually, this either being consumed locally as fuel for drilling other wells in the field or sold to companies drilling wildcats in the vicinity. Since 1931

the field has been closed in and most of the equipment withdrawn. It is doubtful whether it will ever be opened again.

4. *Cacuz well* (Société Française de Recherches au Venezuela), in the District of Urdaneta, State of Zulia, completed in 1930 for 30 bbl. daily. The well was closed in because no facilities for producing it are available and no market for the oil could be found.

5. *Rio de Oro field* (Shell), west of the Colombian border on the southwest side of Lake Maracaibo, in the District of Colon, State of Zulia, operated by the Colon Development Co., Ltd. (Shell). The field is on the north side of the River Rio de Oro, at a distance of about 300 km. southwest of the City of Maracaibo and about 70 km. northwest of the Tarra field, of the same company. Four wells were drilled, two of which were small producers and two dry holes. The field has been shut in for several years, but the wells have been opened once or twice to furnish fuel for drilling wildcats in the vicinity, particularly recently, when the Colombian Petroleum Co. (Texas-Socony) started wildcatting in the Rio de Oro area on the other side of the river, in Colombia.

6. *Misoa field* (C.P.C. and L.P.C.). The Carribean (Shell) drilled its discovery well in 1918 and the L.P.C. its well in 1921. The maximum production obtained from this field was in 1922, when 11,388 bbl. was produced during the year. However, this oil was not used commercially and the field has remained closed in since that date, one well being opened once a year for a few hours, in conformity with the law.

7. *Pauji field* (New England Oil Corporation), in the District of Betijoque, State of Trujillo, where four wells were drilled from 1921 to 1926. A little production was obtained but the wells were considered commercial failures and the field was abandoned early in 1927.

8. *Guanoco field* (New York & Bermudez Co., subsidiary of the General Asphalt of Philadelphia), in the District of Benitez, State of Sucre, about 30 to 35 km. from the mouth of Cano Guanoco, in the Gulf of Paria, eastern Venezuela. The discovery well was drilled in 1913 to a depth of 615 ft., the oil being of a heavy asphaltic base, about 10.9° A.P.I. gravity. A total of 24 wells was drilled in this field, 14 being producers and 10 dry holes. The field was produced until 1932, when it was closed in.

Important Wildcat Wells

1. *Standard Oil Co. of Venezuela.—a.* La Canoa Nos. 1 and 2, near the boundary of District of Independencia, State of Anzoategui, No. 1, was spudded in in October 1935 and temporarily shut down in March 1936. However, although no official reports have been received to this effect, we understand that the well has since been completed at a depth of 3855 ft. and is considered by the S.O.V. as a "closed-in producer," no details being available. No. 2 was spudded in in August 1936, but plugged and aban-

doned at the end of January 1937 as a dry hole, at a total depth of 4618 ft., plugged back to 4450 feet.

b. Maturin Nos. 2, 3 and 4. These wells fall in the pooled area of the Compañia Espanola de Petroleo—Lago—S.O.V., being north of the Maturin village, in the District of Maturin, State of Monagas. These wells were drilled by the S.O.V. for the Spanish company, the L.P.C. also participating in the deal. Maturin No. 2 was drilled exclusively for the purpose of killing Maturin No. 1, which blew out, caught fire and cratered, making it impossible to get in to plug off the gas. No. 2 was drilled to 954 ft. early in 1937, and after serving the purpose for which it was drilled was plugged and abandoned. No. 3 well, north of No. 1, was spudded in in September 1936, and after reaching 4600 ft. was tested in the interval 4531 to 4556 ft., as the Schlumberger survey was reported to have indicated oil shows at this depth. However, the test showed only 32 stands (drill pipe) of muddy water, no other shows were encountered, and the well was plugged and abandoned at 8465 ft. as a dry hole. The fourth and, we understand, the last well to be drilled in this area under the present agreement, was No. 4, spudded in in November 1937, which at the end of the year was drilling at 2370 ft., no oil shows having been encountered up to this depth. Subsequently the well was carried to 4850 ft. without any favorable showings, and is to be abandoned.

c. Terreno Seco No. 1. This well is also in the pooled area of the C.E.P.S.A.—L.P.C.—S.O.V., on the same basis as the Maturin wells, and is 38 km. northeast of these wells, in the Cano La Viuda. It was spudded in in October 1936, and after reaching a total depth of 8583 ft. in November 1937, it was plugged and abandoned as a dry hole.

d. San Juan No. 3, about 30 km. northeast of the Quiriquire field and 3 km. southeast of San Juan No. 1, was spudded in in January 1937, and in May of the same year drilling was temporarily suspended at depth of 4080 ft., because of corrosion of the boilers from the use of salt water, the river having dried up. New boilers were put in but the same trouble developed. Later in the year, after the hole reached a depth of 6085 ft., it was plugged and abandoned as a dry hole.

e. Yabo Nos. 1, 2 and 3. These are S.O.V. wells in the Temblador area, in the District of Maturin, State of Monagas. Yabo No. 1 was spudded in in February 1937 and completed in April at a final depth of 3994 ft., making 575 bbl. daily initial production of 20.2° A.P.I. gravity. The well was afterwards closed in. Yabo No. 2 was spudded in in June 1937 and completed early in September, at a total depth of 3839 ft., plugged back to 3715 ft. No details of the test made at this well are available but it is understood to be shown by the S.O.V. as a "closed-in producer." The third well, Yabo No. 3, was spudded in in October 1937, and after drilling to 9334 ft. was plugged back to 3834 ft. and tested. Found to be a dry hole, it was plugged and abandoned.

2. *Pantepec Oil Co. of Venezuela.*—In March, 1934, a contract was made by the Pantepec Oil Company of Venezuela for the development of oil concessions in eastern Venezuela belonging to the Pantepec Oil Fields Corporation, Alamo Oil Corporation, Venezuelan Pantepec Co. and the American Venezuelan Oilfields, these companies being 100 per cent subsidiaries of the Pantepec Consolidated of Venezuela, Inc., 90.3 per cent of whose stock is owned by the Pantepec Oil Company of Venezuela. The properties involved in this contract with the Standard have an area of approximately 1,000,000 acres; the National Reserves of El Salto, Tabasco and other concessions have been acquired by the S.O.V. for the joint account of this company and Pantepec and, under the drilling contract, the Standard must complete six wells on Pantepec concessions on or before June 29, 1938, either to terminate this agreement and re-transfer all concessions to Pantepec, or to become a permanent partner in these concessions with Pantepec. If the latter happens, Standard may elect either to drill at its own expense 14 additional wells and receive a 50 per cent interest in the concessions and oil discovered thereon, or drill 34 additional wells and receive a 66.6 per cent interest.

The Standard has drilled four wells and is now drilling a fifth one on Standard-Pantepec contract. The first, on the Lirial property (El Lirial No. 1), northern Monagas, was a dry hole. The second and third wells were drilled on El Salto concessions (El Salto Nos. 1 and 2 wells) about 70 miles due east of Oficina No. 1 well (Gulf) and about 75 miles almost due south of the Quiriquire field. Both of these wells have been classified by the S.O.V. as "closed-in producers," although details of tests are not available.

The fourth well (Tabasco No. 1) was drilled on concessions of about 25,000 acres known as Tabasco, about 40 miles east of the El Salto property. Tabasco No. 1 was spudded in in May 1937; a test run showed production of between 400 and 500 bbl. daily, of 14.6° A.P.I. gravity oil through ½-in. choke, and it is estimated that if the well were allowed to flow through the customary 2-in. tubing it would produce more than 6000 bbl. daily.

The fifth well is on El Roble concessions in northern Anzoategui, about 12 miles to the west of the projected pipe line from Oficina No. 2 (Gulf) to the northeast coast (Guanta). This well (El Roble No. 1) is about 15 miles due northeast of the Gulf's Santa Ana No. 1, which has been reported as capable of producing about 650 bbl. daily of 48° A.P.I. oil. El Roble No. 1 was coring at 6103 ft. at the end of the year. It is understood that at 3680 ft. in this well a slight show of oil was observed in the gas in the mud ditch.

The location for the sixth well has not as yet been made.

3. *Lago Petroleum Corporation.*—*a.* Temblador wells. Eleven wells on Lago concessions in the Temblador area were spudded in in 1937, being

drilled by the S.O.V., in the District of Sotillo, State of Monagas. This area was developed during 1937 and, while not shown on the tables as a shipping field, is actually on a producing basis, and facilities are now being completed at Boca de Uracoa for the shipping of this oil.

Of the 11 wells spudded in this area, 3 have been completed as producers, averaging 700 bbl. daily of 20.0° A.P.I. gravity; 3 wells were abandoned, of which number two were dry holes and the third (No. 6) was abandoned on account of mechanical difficulties; 5 wells were still drilling at the end of the year, including an offset well to No. 6 (No. 6*a*) where the rig was skidded off No. 6 and a new hole is to be drilled alongside.

b. El Pilon No. 2. This is an L.P.C. well drilled by the S.O.V. and is also in the Temblador area, in parcel Lago Lot No. 45, to the south of the Temblador wells and due east of Lapa No. 1 well (Gulf). El Pilon No. 2 was spudded in in February and completed in April at 3641 ft. While no details of tests made are available, it is understood that this well is classified by the S.O.V. as a "closed-in producer." El Pilon No. 1, which was completed in October of the previous year, is also classified as a "closed-in producer."

4. *Mene Grande Oil Co. C.A. (Gulf).—a*. Santa Ana Nos. 1 and 2. No. 1 well, which is in the District of Aragua, State of Anzoategui, 45 km. southwest of Santa Rosa No. 1 (Gulf), was spudded in February 1936, and after reaching a depth of 6100 ft. was tested with reported negative results. Upon reaching a depth of 6207 ft. in October 1936, operations were suspended on this well and it remained "standing, incomplete" from that date until the present time. A second well was rigging up at the end of the year, this being east and slightly north of No. 1. This well (Santa Ana No. 2) is scheduled to be spudded in early in 1938.

b. Merey Nos. 1 and 2. These two wells were drilled by the Gulf in the District of Freites, State of Anzoategui. No. 1 was originally spudded in 1934 and operations were suspended in September of the same year. In November 1936, operations were resumed at this well and in April 1937 the well was completed at a depth of 5855 ft., plugged back to 5683 ft. and is reported to be good for about 1000 bbl. daily. This well is 31 km. east and slightly south of El Tigre No. 1 (Gulf). A second well was spudded in in October 1937 (Merey No. 2), almost due west of No. 1, and at the end of the year this well was still drilling.

c. Aero No. 1. This well, near the Merey wells, was spudded in by the Gulf in January 1934, and was suspended at 4477 ft. in March of the same year. Operations were resumed on this well early in 1937 and it was completed on March 18 of that year, at a total depth of 4477 ft., production being obtained. No details of this have been available.

d. Uracoa No. 1. This is a Gulf well drilled by the S.O.V. for the former's account, being in Concession V-394-7 in the District of Sotillo, State of Monagas, east of the Temblador wells and northeast of Tabasco

No. 1 well. It was spudded in in May 1937, and completed at a total depth of 5061 ft., plugged back to 4303 ft. While no details are available, it is understood that this well was completed as a producer and is at present closed in.

e. El Tigre Nos. 1 and 2. These two Gulf wells were drilled by the company itself, El Tigre No. 1 in Lot V-121 in the District of Freites, Anzoategui, spudded in in June 1936. In May 1937, after reaching a depth of 6425 ft., it was plugged and abandoned as a dry hole. El Tigre No. 2, northwest of No. 1, was spudded in in June 1937, and at the end of the year it was still drilling. The latter well is in Parcel V-121-12.

f. Oficina Nos. 1, 2 and 3. These wells are owned and were drilled by the Gulf, in the District of Freites, State of Anzoategui. No. 1 was spudded in in February 1933 and was left standing "incomplete" at a depth of 6184 ft. when operations were suspended at the end of that year. Early in 1937, operations were resumed at this well and in May the well was completed as a producer at a final depth of 6184 ft., plugged back to 5995 ft., reported to have made some 2400 bbl. daily during a test. It is at present closed in. Oficina No. 2 was spudded in in February 1934, 4 km. north of No. 1. Operations were also suspended on this well at the end of 1934, when the well stood as an "incomplete test" at a depth of 6700 ft. Operations were resumed in 1937 and on Sept. 15, 1937, the well was completed as a producer at a depth of 6700 ft., plugged back to 5660 ft., no details of the test made being available. It is closed in at present. A third well was spudded in in November 1937 (Oficina No. 3) and it was still drilling at the end of the year east of Nos. 1 and 2.

g. Lapa No. 1. This is a Gulf well drilled by the S.O.V. for the former's account, in Parcel V-397-6, Lot 10, Municipality Tabsaco, District of Sotillo, State of Monagas. It was spudded in in June 1937 and completed in October of the same year, at 3709 ft., plugged back to 3425 ft. and is understood to be a producer, at present closed in.

h. Hato Nos. 1, 2 and 3. These are Gulf wells, in the Temblador area and drilled by the S.O.V. for the Gulf's account. No. 1 was spudded in in September 1937 and abandoned as a dry hole in December at a depth of 4903 ft. No. 2 was spudded in in September and completed at the end of October 1937, at 3934 ft., plugged back to 3853 ft., making 1500 bbl. daily through ½-in. choke of 21.8° A.P.I. gravity crude oil. No. 3 was spudded in in October 1937, completed in December at 4071 ft., plugged back to 4000 ft. and made 1000 bbl. daily through ⅜-in. choke, the gravity of the oil being 23.2° A.P.I. These wells are at present closed in.

REFINERIES

Caribbean Petroleum Company (*Shell*).—This company has a refinery at San Lorenzo, on the east side of the Lake Maracaibo, 17 km. west of its Mene Grande field. The daily capacity of the refinery is 24,000 bbl., although it is being increased to double this figure, to conform with the new law whereby companies acquiring new acreage for exploitation of oil must, within a certain period, construct a refinery of not less than 10,000 bbl. daily capacity. While the Caribbean Petroleum Co. has not acquired new acreage recently, its associated company, the Venezuelan Oil Development Co., has done so, and rather than build a separate refinery of 10,000 bbl. minimum daily capacity, the Shell is increasing its existing refinery at San Lorenzo.

There is also a canning plant here with a capacity of five thousand 5-gal. cans daily, to take care of the sale of light products inside and outside Lake Maracaibo.

The main refineries of the Shell are outside Venezuela, at Curaçao (C.P.I.M.) and Aruba (Arend Petroleum Mij).

Compania Petroleo de Lago.—This company, formerly known as West Indian Oil Co., the name being changed when the Standard Oil Company of New Jersey acquired the Lago Petroleum Corporation, operates a refinery at La Arriega, on the outskirts of the city of Maracaibo. Its capacity is about 2400 bbl. daily, the crude coming from the La Rosa and Lagunillas fields (L.P.C. and M.G.O.), the latter being royalty oil of the S.O.V. Refined products are sold outside Venezuela but fuel for bunkers processed in this plant is consumed locally.

Lago Petroleum Corporation.—This company (also S.O. Co. of N. J. subsidiary), has a small topping plant at La Salina, known as the La Rosa area, in the District of Bolivar, Estado Zulia. Its capacity is about 5000 bbl. daily. Light products refined here are retailed in the Venezuelan markets.

Mene Grande Oil Co. C.A. (Gulf).—This company owns and operates a small topping plant of about 1800 bbl. daily capacity, in the Cabimas field, District of Bolivar. Fuel and gasoline are processed in this plant for the company's own consumption. The Gulf has no other refinery in Venezuela, its crude being shipped to the deep sea terminal at Paraguana (Venezuela) and from there shipped to its refineries in the United States in ocean-going tankers.

Standard Oil Company of Venezuela.—The S.O.V. has a large refinery at Caripito, State of Monagas, Eastern Venezuela. Its present daily capacity is around 5000 bbl. but this is being increased by 15,000 bbl. to a total of 20,000; four large crude storage tanks now being erected. This increase is being effected for the reason explained under the heading of the Caribbean Petroleum Co., the S.O.V. having acquired considerable new acreage in eastern Venezuela during the past few months. There were rumors that this company would build a separate refinery on the Isla de Margarita to meet this requirement, but finally the company decided to increase the capacity of its existing refinery at Caripito. Fuel oil, gasoline and other light products are processed at Caripito and, apart from supplying its own requirements, the S.O.V. markets light products in eastern Venezuela.

Tocuyo Oilfields of Venezuela, Ltd.—This company has a small topping plant at El Mene de Acosta where fuel for its own consumption is processed and gasoline is manufactured for the retail market in the immediate vicinity.

Deep-water Terminals

Shell.—The Shell does not have a deep-water terminal in Venezuela, all of its crude oil being shipped out of the lake ports in shallow-draft tankers to Curaçao and Aruba. At Curaçao the Shell has a large refinery of 175,000 bbl. daily capacity and at Aruba the Arend has a small refinery with a daily capacity of about 25,000 bbl. From these two points, crude and light products are shipped in deep-sea tankers to the United States and Europe.

Lago Petroleum Corporation (*Standard*).—The L.P.C. has no deep-water terminal within the country, its oil being shipped out in shallow-draft tankers to Aruba, where the company has a large refinery with a capacity of over 300,000 bbl. daily, which is being increased. From this island, crude and light products are shipped in deep-sea tankers to all parts of the world.

Mene Grande Oil Company, C.A. (*Gulf*).—This is the only company with a deep-water terminal within the country. It is on the Paraguana Peninsula, at Las Piedras. Here the Gulf has thirty-seven 80,000-bbl. tanks (total capacity 2,960,000 bbl.) This is only a clearing terminal, there being no refinery or topping plant. In addition to its own storage, the Gulf allows the L.P.C. and S.O.V. to use some of the tanks, allotting some four or five of the 37 tanks for this purpose.

Crude from Las Piedras terminal is shipped in deep-sea tankers of the Gulf, L.P.C. and S.O.V., and customers of the Gulf pick up cargoes of crude in their own or chartered deep-sea tankers.

The Mene Grande Oil Co. C.A. plans to construct a deep-sea terminal at Guanta, near Barcelona, District of Bolivar, State of Anzoategui, within a month or so, for the new production in eastern Venezuela. Roads have been built from the Oficina wells to Guanta and a pipe line is to be laid shortly. It is also understood that another pipe line will be laid from Quiriquire to Guanta, where oil from the S.O.V. fields will be piped and loaded on deep-sea tankers.

North Venezuelan Petroleum Co. Ltd.—This company has a deep-water loading terminal Chichiriviche, in the State of Falcon, District of Silva. It is the clearing terminal for the production of the Tocuyo's El Mene de Acosta field. However, no shipments have been made from this point since early 1935 and as the El Mene de Acosta field was shut down in September 1937, it is not thought that the Chichiriviche terminal will be used in the near future and it will most likely be closed indefinitely. On account of the swampy nature of the land over which the pipe line from the field to this terminal is laid, many breaks have occurred and the maintenance has been extremely costly.

Standard Oil Company of Venezuela.—The Standard has four deep-water terminals—at Caripito, Pedernales, Guiria and Cumarebo. At the Caripito terminal, up the San Juan River although it is called a deep-sea terminal, ocean-going tankers can take only part cargoes, topping off after they have passed out of the river to the mouth where, formerly, the Barge Navahoe (of 92,000 bbl. capacity) was moored. That barge was junked early in 1936 and the Guiria terminal was opened. At the latter, oil was transferred from Caripito in shallow-draft tankers and the deep-sea tankers topped off at Guiria from then on. During periods of rough seas, deep-sea tankers have been topping off at the Maturin Bar, where the shallow-draft tankers from Caripito moor alongside and pump over their cargoes.

The Pedernales terminal, known as "La Brea Terminal," is a deep-water terminal built especially for shipping oil from the new Amacuro and Cotorra wells, known as the Pedernales area, most of the oil going to Aruba.

The Guiria terminal, on the Paria Peninsula, in the District of Capacho, State of Sucre, has been a source of grief to the Standard ever since it was constructed in 1936. Because of the shallowness of the water at this point, the loading lines have had to be laid under water for a distance of some two kilometers, and rough seas at certain periods in the year cause tankers to be torn from their moorings and the submarine lines have been severed repeatedly. Rough seas also cause the movement of oil to be very limited, and on more than one occasion it has been rumored that the Standard would abandon this terminal.

The other deep-sea terminal of the Standard is that of Cumarebo, actually known as "Tucupido," about 6½ miles from the Cumarebo field, on the coast. Oil from the Cumarebo field flows by gravity to this terminal, from which deep-sea tankers load for Aruba and other points abroad.

Proposed Pipe Lines

The Mene Grande Oil Co. is preparing to lay a pipe line from the area in which its Oficina wells are situated, i.e., the District of Freites, State of Anzoategui, northward and slightly to the west through the Districts of Libertad and Bolivar to the coast at Guanta, a distance of more than 400 km. The road has been surveyed and the work of building has begun, and it is understood that the pipe line will be laid within the next month or so.

Another pipe line is under consideration for the wells in the Temblador area to a point on the bank of the Orinoco River to the south, at Barrancas, which lies southwest of the Boca de Uracoa, where the Standard is erecting storage capacity for production from the Temblador field. It is believed that the Gulf and S.O.V. will participate jointly in the laying of the line, it being to their mutual interest.

Standard Oil Company of Venezuela has proposed the laying of a pipe line from Quiriquire to Guanta, connecting with the Gulf's terminal at the latter point, in order to pipe oil from the Caripito terminal direct to this deep-sea terminal, so that tankers will not be obliged to take part cargoes and top off either at the Maturin Bar or at Guiria. In view of the recent contract entered into between the Gulf and the International Petroleum Co. (Standard), whereby the latter will take all the surplus oil of the Gulf from its Maracaibo Lake Basin ports and also new production from eastern Venezuela, it would seem feasible that the S.O.V. would wish to make Guanta its principal deep-water terminal in eastern Venezuela.

Chapter VI. Refining

Review of Refinery Engineering for 1937

By Walter Miller,* Member A.I.M.E.

Construction of new large refineries was small in 1937, but extensive modernization and expansion of existing plants were made, bearing out the observation of the Bureau of Mines that the trend is strongly toward fewer and larger refineries. Building the first large combination skimming and cracking unit of 20,000-bbl. capacity was a startling achievement four or five years ago, but it has been exceeded many times since, and at least four units with a capacity of 30,000 bbl. or more were contracted for during 1937, as well as many other units of smaller but still substantial capacity.

Installation of polymerization plants for producing high-antiknock blending naphthas from refinery gases progressed at an accelerated rate in refineries affording sufficient raw gas to make the use of the process profitable. The total productive capacity of polymerization units built and contracted for in the United States is now about 25,000 bbl., equivalent to the gasoline production from approximately 55,000 bbl. of crude oil a day.

Octane Fuels

Also utilizing refinery gases—the butylene fractions in particular—the plants for manufacture of iso-octane increased in number to such an extent that the combined capacities will enable the air forces of the United States shortly to go entirely to the use of 100-octane fuel, indications being that the Army will reach that position in 1938, with the Navy not far behind. Commercial air-lines are expected to take advantage of the greater power of high-antiknock fuels to gain the increased power and increased pay loads possible with their use. Work done on producing fuels with octanes beyond the 100 point has recently been reported, and their production can be expected, although at high cost, when the economics of the situation justifies and engines capable of utilizing them efficiently are available.

In the field of motor fuels, important work was reported to the A.P.I. at its annual meeting, on the effect of altitude on antiknock requirements

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of cars. This work showed that gasoline for use in high altitudes need not carry nearly as high an octane rating as that required at elevations from sea level to a few hundred feet above. The conclusion stated was that for average cars the decrease in octane requirements to suppress detonation varied from three octane numbers for the first thousand feet above sea level to as high as 7.5 units per 1000 ft. difference at 12,000 ft. above sea level.

General agreement was reached by its licensees with Ethyl Gasoline Corporation regarding changes in octane determination methods, first broached by the corporation in 1936, as a result of which the L-3 method was put into effect as leading to greater and more uniform accuracy. The limits were changed from 70 to 72 maximum for nonpremium house-brand gasoline, and from 76 to 78 minimum for premium gasoline, these changes being made effective on Sept. 1 and Oct. 1, 1937, respectively. The change necessitated the use of approximately 1 c.c. more ethyl lead in house-brand gasolines. It is not thought that this small change will of itself materially add incentive to extension of refining methods that compete with tetraethyl lead in increasing the octane number.

Refinery Capacities

Demand for refined products forced operations to the all-time high figure of 3,450,000 bbl. a day in September. The question of the country's true refinery capacity, which has for years bothered the industry, progressed much nearer a solution by action of an A.P.I. committee, which collaborated in revising the questionnaire form to be issued by the U. S. Bureau of Mines for its Jan. 1, 1938, capacity survey, and set up definitions that should result in accurate figures. Cooperation of refiners in reporting the actual capacities of their plants is confidently expected.

The trend toward a more even distribution of total products is still noticeable. Domestic fuel-burner installations continued at a high rate, affording a greater rate of increase in furnace-oil use than in gasoline consumption. This trend is having the effect of minimizing seasonal fluctuations in volume of refinery operations, and holding in check and even slightly reducing gasoline recovery from crude oil.

Cracking

Technical advances in cracking were evidenced by greater accuracy in design. Maximum capacities of units constructed approached designed capacities much more closely than before, resulting in less unpremeditated excess capacity. An innovation was the completion of two small cracking units, one in Michigan and one in Pennsylvania, following a modified design of the True Vapor Phase process unit installed some seven years ago in the Shell Company's Wood River plant. The cracking patent situation was considerably clarified by a new agreement between the owners of the largest two licensing groups. Although it is impossible to predict whether or not this will have the effect of extending a monopoly which in the opinion of many has been overcostly to the refining industry, it did result in the immediate dismissal of several pending infringement suits, the abandonment of plans to institute a number of others, and the saving of many headaches to the owners and licensees of the hitherto warring groups.

Gasoline Blends

The pressure exerted previously to force blending of alcohol with gasoline seems to have abated somewhat during the year. Reports regarding difficulty encountered in persuading farmers to grow starch crops at a price that would make the alcohol blend competitive with current gasoline prices lend support to claims that a move of this kind under present-day conditions would result in a subsidy to the farmers, raised probably in the form of higher costs to the gasoline-consuming public. The manufacture of about 12,000 gal. a day and its distribution in gasoline blends in Kansas, supported by the Chemical Foundation, continued throughout the year.

Improvements in Processes

Some additional solvent-treating and solvent-dewaxing capacity was added during 1937, but not commensurate in volume with the years immediately preceding. Increased power output demanded of the more advanced automobile engines, involving higher engine speeds, temperatures, and bearing pressures, will constitute a severer test for solvent-treated oils. On the other hand, bearing manufacturers have progressed toward reducing the corrosion susceptibility of some of the more sensitive bearing materials.

Interest in addition agents to impart specific qualities to lubricants increased greatly, some worth-while new developments being brought out.

A pre-coat, continuous rotary vacuum filter to take the place of the older type plate press for removal of clay in the contact treating process was proved in service.

Through and beneath the progress in refining was the continual study of corrosion and heat-resisting metals. The silicon-aluminum steels appear promising from the standpoint of corrosion resistance, whereas in the nonferrous group the Admiralty brasses with antimony inclusion seem to offer protection against dezincification.

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